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American Institute of Electrical Engineers

COMING MEETINGS

Midwinter Convention, New York, N. Y., February 8-11

Annual Business Meeting, New York, N. Y., May 21

Annual Convention, White Sulphur Springs, W. Va., June 21-25

Pacific Coast Convention, Salt Lake City, Utah, (Dates to be announced in subsequent issue)

Middle Eastern District, A. I. E. E., Cleveland, Ohio, March 18-19

Northeastern District, A. I. E. E., Niagara Falls, May 26-28

MEETINGS OF OTHER SOCIETIES

New York Electrical Society, Engineering Societies Bldg., New York, N. Y., December 9

The American Physical Society and Section B of the American Association for the Advancement of Science, (Joint Meeting), Kansas City, December 28-30

National Electric Light Association, Atlantic City, N. J., May 17-21

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Journal of the A. I. E. E.

Devoted to the advancement of the theory and practise of electrical engineering and the allied arts and sciences

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Chandler: the Teacher and the Chemist

The history of Charles Frederick Chandler's life is an essential part of the history of chemistry and chemical engineering in the United States during the last sixty years. In the early fifties, when young Chandler entered the Lawrence Scientific School at Harvard, chemical science in England and in this country was practically a monopoly of the druggists. Those were the days when the druggists in England were called chemists, and the name has persisted down to the present day. Young Chandler had to leave the Lawrence Scientific School and go to Professor Woehler of Göttingen, in order to study the science of chemistry. Neither Harvard nor any other college in the United States was equipped in those days for training students in chemistry. When Chandler returned in 1857, decorated with a Göttingen Ph. D. degree, nobody seemed anxious to engage his services. He finally found some odd jobs with the oil men of New Bedford, analyzing their whale oil. His old friend, Professor Joy of Union College, needed his assistance in the College laboratory, but the trustees were unwilling to appropriate a salary for an assistant in chemistry after they had appropriated five hundred dollars for a janitor of the chemical laboratory. The young doctor of philosophy took the vacant position of janitor. The privilege of giving scientific assistance to the professor of chemistry attracted him to the position of janitor. Nothing can describe better the state of the Chemical science in this country in those days than this beginning of Chandler's scientific career. Nothing can describe better the latent energy of the young doctor of chemistry than his willingness to start his career as a janitor.

Who can tell today how long Chandler would have had to stay as janitor at Union College, if Professor Joy had not been called to Columbia College in 1857? But Joy stepped out of Union College and the trustees advanced Chandler from janitor to professor. Chandler's biography, entitled "From Janitor to Professor," would furnish a story of eminent value to the history of American science. Chandler soon outgrew his position at Union College and joined his old friend Professor Joy at Columbia College, where with Eggleston and Vinton he started an enterprise which is unique in the history of engineering education in this country. They started the School of Mines of Columbia College with no salary and no financial assistance from the trustees. Chandler was less than thirty when he became dean of the new school. The trustees of Columbia College were the typical college trustees of those days: lawyers, clergymen, and gentlemen of leisure. The conservatism of men of that type would have hardly countenanced the venture of Chandler, Eggleston, and Vinton, if Barnard had not been elected in that very year president of Columbia College. To them the venture would have looked very much like an adventure. But Barnard, although a Reverend, was one of those American scientists of vision who at the end of the Civil War started the new movement for higher endeavor in all our intellectual activities. Joseph Henry, John Draper, Barnard, and Andrew White were the prophets of the new movement, which needed young apostles full of action, enthusiasm, training, and discipline. No young scientist in those days was better qualified than Chandler to preach the gospel of salvation which science promised to those who believed in it. Chandler became the apostle of the Chemical Science in the City of New York. One who knows the history of this apostolic mission cannot help seeing a striking similarity between Chandler's scientific activity in the American metropolis fifty years ago, and the apostolic mission of St. Paul in Athens and of St. Peter in Rome. The mental attitude of the New York alderman and politician of fifty years ago was not a bit more kindly disposed to the gospel of science than the mental attitude of the Roman politician was to the gospel of Christianity. If American democracy had permitted it Chandler would have shared the fate of St. Peter. But fortunately there were in those days men in high places like Doctor Harris, of the Board of Health, and the Mayors Havemeyer and Ely who were converted by Chandler's gospel of science. His study of and report upon the sanitary problems of the city of New York opened their eyes. Chandler became the consulting chemist of the Board of Health and in 1873 its president. By reappointment he continued in presidential authority until 1883. During this period of ten years Chandler created the science of Sanitary Engineering and the science of nursing and public health, and demonstrated their power in protecting the health and the life of the metropolitan population.

No belief is stronger today in the hearts of scientific men and engineers than the belief that in a democracy like our democracy science and engineering must form an essential part of our national government, and that the leaders of our scientific activities must be in closest contact with our national problems. Chandler was one of the earliest apostles of this belief, and he preached its gospel not only to the politicians but also to the captains of industries. Fifty years ago the mental attitude of the New York captains of industries with regard to science was just as hostile as that of the New York aldermen. They were all from Missouri and wanted to be shown, and it required the discipline, the enthusiasm, the courage, and the inexhaustible energy of a Chandler to do the showing. He won them all and they ultimately became his friends and admirers. One of our greatest national assets today is the wonderful cooperation between American science and American industries; Chandler was one of the earliest advocates of this cooperation. His official position as president of the Board of Health of New York compelled him often to demonstrate before the courts that a metropolitan chemical industry which refuses to grasp the guiding hand of science is destined to become a public nuisance. The advocate of a good cause who is not too proud to fight is bound to win. Chandler was never too proud to fight for the cause of science, and he won many legal victories for the claims of science in the municipal administration of New York.

During my earliest student days at Columbia I was devoted to modern and classical literatures, to physics and mathematics. The science of chemistry had no fascination for me. It was in my untutored opinion, too sloppy, too wet, and too empirical. The chemical laboratory, I thought, looked like a drugstore or a dispensary, and smelt like a hospital. But one day I heard of Chandler's lectures and I made up my mind to try them. I tried them, and I became one of Chandler's boys during the remainder of my college career. Later, when he and I had become colleagues, I told him that he never met a New York alderman of fifty years ago who had a smaller knowledge of chemistry and larger prejudice against it than I had when as a sophomore of Columbia College I first entered his lecture room. "Then how in the world," asked Chandler, "did I manage to draw you away even temporarily from the ethereal heights of

Address delivered at a Memorial Meeting, November 16, 1925, in honor of the late Charles Frederick Chandler.

Homer, Shakespeare, Newton, and Faraday and induce you to to listen to my prosy language of chemistry?"

But Chandler's language of chemistry was never prosy. It was a thrilling epic which Chandler recited when, for instance, he described the wandering of the carbon atoms from the carbon dioxide of the atmosphere. One could see them glide along the beams of golden sunlight and plunge into the loving arms of chlorophyl after bidding goodbye to their deserted oxygen partners. The wanderings of Ulysses as described by Homer are a prosy tale when compared with the wanderings of the carbon atoms through the labyrinths of organic life, in the vegetable and animal kingdom, to appear again in the busy stream of the living blood where they meet their former partners, the deserted oxygen atoms, and unite with them for a honeymoon of blissful idleness. Oxygen and carbon atoms no longer appeared to me like mere symbolic entities, carrying on their backs, like state prisoners, a mysterious number, which told me nothing beyond the meaningless tale of their atomic weight. Chandler's epic revealed them to me as my most precious personal friends who toiled day and night in order to keep me alive. There was not one among the many chemical elements which did not play a leading part in some of Chandler's epics of chemistry, which he recited with matchless art. It is no wonder that students flocked to the School of Mines, the School of Pharmacy, and to the College of Physicians and Surgeons, in order to enlist in the ranks of Chandler's boys.

M. I. PUPIN

Some Leaders of the A. I. E. E.

Louis A. Ferguson, twenty-first President of the Institute, was born in Dorchester, Massachusetts, August 19, 1867. His education included several years in the Boston Public Schools and the Dorchester High School and the Electrical Engineering Course at the Massachusetts Institute of Technology, from which he was graduated in 1888 with the degree of B. S. His thesis on the "Relations Between Candle Power, Voltage, and Energy Consumption of Incandescent Lamps" turned his thoughts definitely to the Central Station field and he went directly from the Institute to the underground distribution department of the Chicago Edison Company.

In 1890 he was appointed electrical engineer in charge of all electrical engineering and electrical construction work of the company. Three years later his duties were enlarged to include supervision of all soliciting and contract work, in which field he was especially successful in conducting negotiations for long term contracts with some of Chicago's largest mercantile and industrial establishments. In 1897 he was appointed general superintendent of the Chicago Edison Company and a year later also general superintendent of the Commonwealth Edison Company. As general superintendent there was added to his duties the supervision of the Operating Departments of the Company. In 1902 he was elected second vice-president of both Companies, in charge of Contract, Operating, Construction and Electrical Departments, and has been vice-president with the same duties through the subsequent consolidations.

In the technical field Mr. Ferguson was the first Central Station engineer in the Country to recommend the system now so generally adopted— three-phase alternating current transmitted to substations with rotary conversion to direct current for general distribution. He has made notable contributions to the development of low tension distribution, and continued his early work on illumination units with special studies of acetylene gas. He has kept in close touch with European engineering development through frequent trips, made in each case just before the inauguration of some large project in Chicago to which he was thus prepared to apply a cosmopolitan view of American methods.

It was on the strength of his careful investigation of European practises and conditions as set forth in his subsequent report and recommendations to the Chicago Edison Company, that the system of differential rates—known as the Wright Demand System—which has had such a vital influence in the development of our American rate structure, was introduced in the United States.

In 1888 when he entered the service of the Chicago System the original Adams Street Station of the Chicago Edison Company with its four 200 h. p. non-condensing engines and belted direct current generators was just nearing completion. Today the Commonwealth Edison Company has nine principal generating stations with a combined capacity of 870,000 kw., a principal underground high tension transmission system of 1300 miles, supplying 80 substations aggregating 747,000 kw. owned by the Company, and 21 substations aggregating 143,000 kw. owned principally by railway companies.

This development has been largely the story of Mr. Ferguson's life, which has been devoted to the progress of the Commonwealth Edison Company and its predecessors.

In addition to his service to the Institute, Mr. Ferguson has been President of the National Electric Light Association and of the Association of Edison Illuminating Companies. He is a Director of the Middle West Utilities Company and of the Public Service Company of Northern Illinois, and President and Director of Minerallac Electric Company. He is also a member of many Chicago clubs and organizations.

The New England Power Conference

Last month a memorable conference upon power development in New England was held at Worcester. Under the chairmanship of Samuel Ferguson, more than 600 delegates from business and utility organizations heard Owen D. Young, Martin J. Insull and Dexter P. Cooper discuss the value of power pooling, of interconnection and of the engineering development of the electrical resources of the Northeast. Thus a new point of contact between power producers, distributors and users was found. The sound economic lessons set forth were broadcasted by press and radio and served effectively to explain to the public at large the meaning of active and important tendencies in electrical supply. Conceived in connection with a broad movement among state governors to unite New Englanders for the common good, the conference achieved a triumph in economic publicity and made no little headway against the doctrine of limiting power pooling by political barriers.

Although many engineers and utility men attended, the meeting avoided technicalities and was devoted to bringing about a better understanding of the economies of power supply and a closer alliance between the utilities and their customers. In this connection the pressing problem of electric service to farmers was briefly discussed, and Mr. Ferguson's recommendation that temporarily the city companies should bear the burdens of unprofitable rural extensions aroused much interest. Another session, devoted to agriculture, emphasized the growing importance of the farmer in the development of the state, and a third, on marketing, rounded out the program. Present indications are that conferences of this kind will be conducted in the future as a proved method of solving regional problems, and if this is done, the electrical industry, with its close connection with almost all branches of commerce and manufacture, will play an important part in the work. Such gatherings as this open the way toward group cooperation, long found of the utmost value within the electrical industry itself, and the men of the Northeast are to be congratulated upon so constructive a step in the field of mutual understanding and team play for the welfare of the New England States.—*Electrical World.*

Oscillographic Solution of Electromechanical Systems

BY C. A. NICKLE[1]

Associate, A. I. E. E.

Synopsis.—A simple and practical method has been developed for investigating certain important classes of dynamic systems, as represented, for instance, by a power system comprising synchronous or induction generating units, with prime movers, connected through transmission lines to receiving apparatus of the same character. The behavior of individual units, of course, can also be investigated, —such as the important case of determining the current pulsation of a synchronous motor driving a reciprocating compressor; or, purely mechanical systems involving moving masses and resilient members, such as beams, bus bars, etc., under the influence of suddenly applied load. In the present paper, the method is described and its application to a few of the possible cases is illustrated.

The method is, to have an "equivalent electrical circuit" solve the problem, and the oscillograph plot the solution. The idea is based on the fact that if the differential equation for an electric circuit is identical with that for the dynamic mechanical system in question, then the corresponding electrical quantities can be taken to represent quantitatively the actual mechanical quantities. The equivalent circuit can be easily set up, and oscillographic records of the voltages and currents constitute the plotted solutions.

The chief value of the scheme lies not only in one's being able to easily solve a given, complicated, problem, but also in the facility with which the effect of change in design factors may be determined.

The method is capable of considerable extension. Its application is limited only by the extent to which circuit elements of the proper characteristics can be found. The treatment given here considers only those cases which involve the circuit elements L, C and R, and in which these are constant.

MATHEMATICAL analysis of mechanical and electro-mechanical dynamic systems, such as, for instance, a modern power system as a whole or individual power units, becomes complicated very rapidly as the number of degrees of freedom is extended. When the limit of practical mathematical solution is reached, it is possible to resort to graphical methods, which may be effectively employed within a limited field. Such methods were carried to unusual limits in a recent investigation by Booth and Bush[2], which demonstrated the efficacy, and also indicated the limitations, of those methods. Many practical power systems, nevertheless, extend far beyond such limits yet, the importance of their solution is certainly no less. On the contrary, it is perhaps greater.

A simple method has been developed for investigating systems of this general character. It involves the use of the oscillograph in connection with electrical circuits, in which the electrical quantities represent the mechanical quantities of the actual system. In any given problem the procedure is to sketch out the equivalent circuit according to definite principles, merely by an inspection of the diagram of the actual system. The equivalent circuit, described later, usually comprises batteries, inductances, capacities and resistances of appropriate values. Oscillographic records of the currents and voltages in the various circuit branches, following some disturbance, constitute the *plotted solutions* of the differential equations of the system—plotted against time to a definitely known scale of torque, speed, displacement, power, etc. The method thus brings within practical reach, the solution of extremely complicated problems relating not only to power systems, but also to *any* system for which an equivalent circuit can be set up.

HISTORICAL

The idea of analogous systems has been employed for many years as an aid in visualization, explanation and mathematical analysis. The same differential equation may represent many different natural phenomena; which means, of course, in each case, that the quantities expressed vary with respect to each other in precisely the same manner. Thus, analogies follow; and electrical engineers have been quick to utilize them in the analysis of many problems. Arnold[3] has extended such analogies to the use of equivalent electrical circuits in the mathematical analysis of problems. While this usually affords a clearer conception of the problem, and may sometimes facilitate the handling of mathematical expressions, nevertheless, the expressions still remain to be handled.

In the present paper, the idea is carried a step further. The mathematical processes are eliminated altogether by having the electrical circuit solve the problem, and the oscillograph plot it. So, instead of tedious equations perhaps hopeless of solution even with such aid in mathematical treatment as the analogous circuits may give, one has available in the present oscillographic method, practical and simple facilities for analysis.

PREMISES

The fundamental basis for the method is that the differential equations for the equivalent circuit are of exactly the same form as those for the actual system. Since the equations are of the same form, the electrical quantities which occur in the equations for the equivalent circuit may be considered to represent the physical quantities which occur in the equations for the actual system. As will be shown later, if we choose inductance

1. Of the General Electric Co., Schenectady, N. Y.

2. Power System Transients, JOURNAL, A. I. E. E., March, 1925, p. 229.

Presented at the Regional Meeting of Dist. No. 1, Swampscott, Mass., May 7-9, 1925 also at the Annual Convention, Saratoga, N. Y., June 22-26, 1925.

3. *Die Wechselstromtechnic*, Vol. IV, page 379.

to represent mass, and electrical charge to represent displacement or length, time being common to both systems, it will be found that the differential equations are of exactly the same form, and, furthermore, that the various phenomena occurring in the physical system are represented by quantities in the equivalent circuit which are convenient to measure, that is, voltage and current.

Assuming, for the present that, these representations are the most advantageous, Table I can at once be constructed.

TABLE I

Mechanical System				Electrical System
mass	M			$\mathfrak{L}$ inductance
length	L			Q charge
time	T			t time
Derived quantities		Dimensions	Dimensions	
force	F	$M\,L\,T^{-2}$	$\mathfrak{L}\,Q\,t^{-2}$	E voltage
velocity	V	$L\,T^{-1}$	$Q\,t^{-1}$	I current
damping constant	K_d	$\frac{F}{V}$	$\frac{E}{I}$	R resistance
resilience constant	K_r	$\frac{L}{F}$	$\frac{Q}{E}$	C capacity

In general, however, it is not desirable to use Table I for quantitative representation, since this would often require very large and impracticable electrical units. In order that the electrical units shall be of reasonable magnitude, we can let one unit of mass be represented by a units of inductance, one unit of time in the physical system by b units of time in the electrical system and one unit of length by c units of charge. Then, by arbitrary choice of the conversion factors a, b, and c, the order of magnitude of the quantities in the electrical circuit can be made any desired value. Introducing the conversion factors, Table II may be constructed.

TABLE II

Mechanical System		Conversion Factors[4]	Electrical System
mass	M	a	$\mathfrak{L}$ inductance
length	L	c	Q charge
time	T	b	t time
Derived quantities			
force	F	$\frac{a\,c}{b^2}$	E voltage
velocity	V	c/b	I current
damping constant	K_d	a/b	R resistance
resilience constant	K_r	b^2/a	C capacity
power	$F\,V$	$\frac{a\,c^2}{b^3}$	$E\,i$ power

In the differential equations for systems in rotation, the moment of inertia corresponds to mass in systems in translation, angle corresponds to length, and time is the same for both systems. Hence the table for systems in rotation may be written at once, as shown in Table III.

TABLE III

Rotational System		Conversion Factor	Electrical System
moment of inertia	I	a	$\mathfrak{L}$ inductance
angle	θ	c	Q charge
time	T	b	t time
Derived quantities			
torque	$\mathfrak{T}$	$\frac{a\,c}{b^2}$	E voltage
angular velocity	ω	c/b	i current
damping constant	$\mathfrak{T}_d$	a/b	R resistance
resilience constant	$\mathfrak{T}_r$	b^2/a	C capacity
power	$\mathfrak{T}\,\omega$	$\frac{a\,c^2}{b^3}$	$E\,i$ power

In the present treatment, only physical systems, in translation or rotation, in which existing forces are proportional to $\frac{d^2 x}{d\,t^2}$, $\frac{d\,x}{d\,t}$, and x, will be considered, where x represents length or angle; in other words, only physical systems which may be expressed by linear differential equations will be taken up.

A composite system, of which the component parts are expressible by linear differential equation, is itself expressible by a linear equation of higher order and may be represented by a composite electrical circuit.

Obviously the method is not limited to problems in mechanics alone, but may be used as a means of solution of any problem which may be expressed by linear differential equations. However, the method is not necessarily limited to linear systems only. If electrical circuits can be devised which have characteristics varying in exactly the same manner as the characteristics of the system to be solved, then the method is applicable. In general, this would require resistances, capacities and voltages which should be variable in accordance with certain prescribed laws. This might, in many cases, be entirely feasible as is demonstrated in the representation of governor action, described in Appendix A.

Equivalent Circuits

Fig. 1 illustrates some elementary physical systems and their equivalent electrical circuit.

A brief inspection of the familiar differential equations for the various cases shows that they are of exactly the same form and, hence, their solutions must be of the same form.

Case A represents a mass and spring with one end of the spring attached to an immovable support, and having the mass constrained to move in a bath which is assumed to give a damping force proportional to the velocity of the mass M. Comparison of the equations

4. (Mechanical quantity) × (conversion factor) = (electrical quantity). Thus, $C\,L$ feet = Q Coulombs, $V\,c/b$ feet per sec. = amperes, etc.

for Case A and Case D shows at once that mass in the physical system is represented by the inductance in the electrical circuit, and length, by charge, time being the same for both systems. From Table I, force should be represented by voltage, the damping constant, by resistance, the resilience constant, by capacity, and velocity, by current. These relations all exist respect-

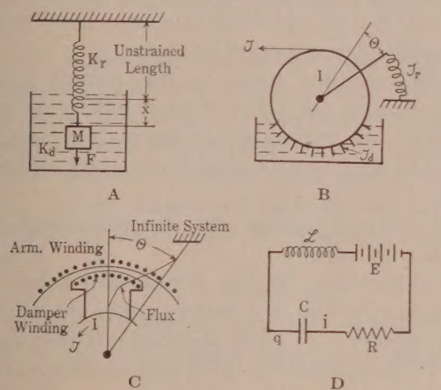


FIG. 1—SYSTEMS REPRESENTED BY THE SAME DIFFERENTIAL EQUATION

(A)

$$M \frac{d^2 x}{d t^2} + K_d \frac{d x}{d t} + \frac{1}{K_r} x = F$$

$$M \frac{d V}{d t} + K_d V + \frac{1}{K_r} \int V d t = F$$

(B)

$$I \frac{d^2 \theta}{d t^2} + \mathfrak{T}_d \frac{d \theta}{d t} + \frac{1}{\mathfrak{T}_r} \theta = \mathfrak{T}$$

$$I \frac{d \omega}{d t} + \mathfrak{T}_d \omega + \frac{1}{\mathfrak{T}_r} \int \omega d t = \mathfrak{T}$$

(C)

$$I \frac{d^2 \theta}{d t^2} + \mathfrak{T}_d \frac{d \theta}{d t} + \frac{1}{\mathfrak{T}_r} \theta = \mathfrak{T}$$

$$I \frac{d \omega}{d t} + \mathfrak{T}_d \omega + \frac{1}{\mathfrak{T}_r} \int \omega d t = \mathfrak{T}$$

(D)

$$L \frac{d^2 q}{d t^2} + R \frac{d q}{d t} + \frac{1}{C} q = E$$

$$L \frac{d i}{d t} + R i + \frac{1}{C} \int i t d = E$$

ively in the two sets of equations, and therefore, Case D is a true representation of Case A. A sudden application of force on the mass M is given by a sudden application of voltage. The voltage across the inductance then gives the inertial force of the mass; the voltage across the condenser C is a measure of its charge, and thus gives both the displacement of the spring and the displacement force; the voltage across the resistance R gives the damping force of the liquid on the mass; and the current in the circuit gives both the velocity of the mass and the rate of change of displacement between the two ends of the spring, these velocities being the same since the support is immovable.

Similar reasoning applies to Case B, except that the electrical quantities are interpreted in terms of rotation instead of translation.

Case C represents a synchronous machine connected to an infinite system. In this case the voltage across the condenser gives the synchronous torque of the machine due to the displacement of the rotor from the terminal voltage; the charge on the condenser gives the angular displacement of the rotor from the phase of the terminal voltage; the voltage across the resistance gives the damping torque due to the amortisseur winding, and the current gives the velocity of the rotor with respect to the terminal voltage: that is, the departure of

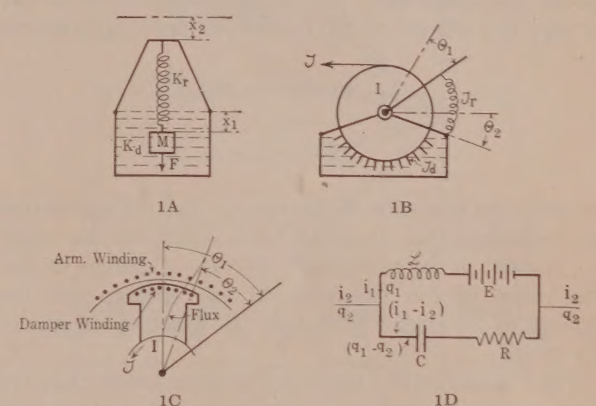


FIG. 2—SYSTEMS REPRESENTED BY THE SAME DIFFERENTIAL EQUATION

(A)

$$M \frac{d^2 x_1}{d t^2} + K_d \left(\frac{d x_1}{d t} - \frac{d x_2}{d t} \right) + \frac{1}{K_r} \left(x_1 - x_2 \right) = F$$

$$M \frac{d V_1}{d t} + K_d \left(V_1 - V_2 \right) + \frac{1}{K_r} \int \left(x_1 - x_2 \right) d t = F$$

(B)

$$I \frac{d \theta_1}{d t^2} + \mathfrak{T}_d \left(\frac{d \theta_1}{d t} - \frac{d \theta_2}{d t} \right) + \frac{1}{\mathfrak{T}_r} \left(\theta_1 - \theta_2 \right) = \mathfrak{T}$$

$$I \frac{d \omega_1}{d t} + \mathfrak{T}_d \left(\omega_1 - \omega_2 \right) + \frac{1}{\mathfrak{T}_r} \int \left(\omega_1 - \omega_2 \right) d t = \mathfrak{T}$$

(C)

$$I \frac{d^2 \theta_1}{d t_2} + \mathfrak{T}_d \left(\frac{d \theta_1}{d t} - \frac{d \theta_2}{d t} \right) + \frac{1}{\mathfrak{T}_r} \left(\theta_1 - \theta_2 \right) = \mathfrak{T}$$

$$I \frac{d \omega_1}{d t} + \mathfrak{T}_d \left(\omega_1 - \omega_2 \right) + \frac{1}{\mathfrak{T}_r} \int \left(\omega_1 - \omega_2 \right) d t = \mathfrak{T}$$

(D)

$$L \frac{d^2 q_1}{d t^2} + R \left(\frac{d q_1}{d t} - \frac{d q_2}{d t} \right) + \frac{1}{C} \left(q_1 - q_2 \right) = E$$

$$L \frac{d i_1}{d t} + R \left(i_1 - i_2 \right) + \frac{1}{C} \int \left(i_1 - i_2 \right) d t = E$$

the rotor from synchronous speed. It should be noted that the assumption of direct proportionality between synchronous torque and displacement angle has been made. Although this is not rigorously true, nevertheless, for small angles the assumption is, of course, justifiable.

If the capacity in the circuit is made infinite, the synchronous torque becomes zero leaving only the damping torque. *The circuit is then evidently the representation of an induction motor.*

In the more general case, the supports are not immovable, but also have a velocity and displacement which are functions of time. Fig. 2 illustrates this condition.

Inspection of the respective differential equations shows that they are of exactly the same form as those for the equivalent circuit. Hence, for Case A and Case D the voltage across the inductance gives the inertial force of the mass; the current in the inductance gives the absolute velocity of the mass; the voltage across the condenser, the displacement force of the spring; the charge on the condenser, the displacement

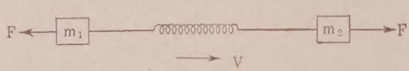


FIG. 3

between the two ends of the spring; the voltage across the resistance, the damping force acting on the mass; the current in the condenser, the rate of change of displacement of the two ends of the spring, and the current in the circuit terminals, the speed of the end of the spring.

The reasoning for Case B is the same except that the electrical quantities are interpreted in terms of rotation instead of translation.

For Case C, the velocity of the rotor is represented by the current in the inductance; the velocity of the terminal voltage is represented by the current in the circuit terminals; the displacement of the rotor from the bus is given by the charge on the condenser; the synchronous torque, by the voltage on the condenser; the damping torque, by the voltage across the resistance; and the relative velocity of the rotor with respect to the terminal voltage, by the current in the condenser.

The characteristics of a transmission line are such that the power transmitted over the line, and the torque corresponding to it, are proportional approximately to the sine of the angle of displacement between the terminal voltages. Rigorous representation of such a characteristic would require a condenser the capacity of which is a sine function of the charge. It has been found, however, that for displacements of the magnitude customarily encountered in practise, the torque may be taken as proportional to the angular displacement[5].

For such an assumption, the transmission line will evidently be represented in the equivalent circuit by a condenser, just as in the case of the spring.

In certain cases, such as power systems, the variation in speed of the component parts may be of relatively small magnitude compared with the total speeds. Since motion is purely relative, any constant value of speed may be taken as a reference. The actual choice of this reference will be largely determined by the nature of the problem under consideration. If every part of the system is initially moving at the same speed, the logical reference point is this initial speed. For such a case, the relative initial speed of each component part with respect to this reference is, of course, zero, and, since current in the equivalent circuit represents speed in the actual system, the initial currents in every part of the equivalent circuit must be zero.

Now, for constant speed in the actual system, Σ torques acting on the rotor of each unit must be zero. These conditions impose on the equivalent circuit that,

(a) all initial currents must be constant and equal to zero, and,

(b) Σ voltages acting on the individual inductances must be zero.

As an illustration, let Fig. 3 represent a mechanical system in equilibrium, the entire system traveling at an absolute velocity V. To an observer also moving at the velocity V, the system will, of course, appear stationary; that is, with respect to the velocity V as a reference, the relative velocity of the entire system is zero. Now, if one of the forces is suddenly changed to a new value, the observer at velocity V will note certain velocities in the various parts of the system as functions of time, while to a stationary observer every velocity will be different by V. Evidently, therefore, the speed of the observer will have no effect upon the other phenomena such as forces, relative displacements in the system, etc.

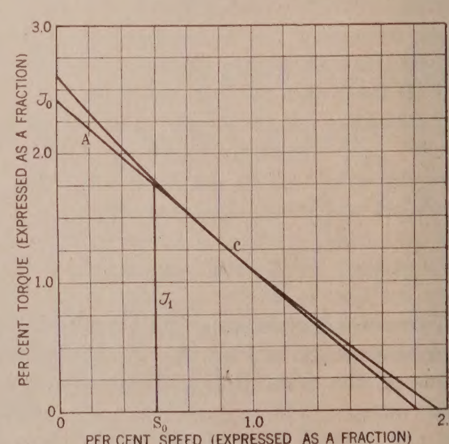


FIG. 4—SPEED-TORQUE CHARACTERISTIC

For systems, initially in motion, it is thus possible to obtain an equivalent circuit in which the currents all differ from the actual equivalent currents by a constant, without changing the performance of the circuit.

Use of this principle is made in developing a representation of certain prime mover torque-speed characteristics.

Fig. 4 shows a typical torque-speed characteristic for a waterwheel with full load gate opening held con-

5. The relation between power and angular displacements between the voltages at the ends of a transmission line is shown in the paper by Bush and Booth, on Power System Transients, JOURNAL, A. I. E. E., March, 1925, Vol. XLIV, No. 3, page 233.

stant. If the waterwheel is initially operating at point C, then for considerable variations in speed, the characteristic is essentially the straight line A tangent to the actual characteristic at C. The equation of line A is

$$\mathfrak{T} = \mathfrak{T}_0 - K s \qquad (1)$$

where

$\mathfrak{T}$ = torque at any speed s.

$\mathfrak{T}_0$ = intercept of line A with the Y axis.

and

K = the numerical value of the slope of the line A.

In accordance with the foregoing, since it is desirable in the interest of accuracy to choose some speed other than zero as the reference speed, let s_0 be the reference speed with respect to which other speeds are to be measured. Then, since the slope of the line is of course not changed by the choice of reference, the general equation is

$$\mathfrak{T}' = \mathfrak{T}_1 - K (s - s_0) \qquad (2)$$

where $\mathfrak{T}'$ = the torque at any relative speed $(s - s_0)$

and $\mathfrak{T}_1$ = the torque when the relative speed is zero. That is,

$\mathfrak{T}_1$ = the ordinate of the line A at the reference speed s_0.

In the equivalent circuit, torque is represented by voltage and speed by current. Hence, corresponding to

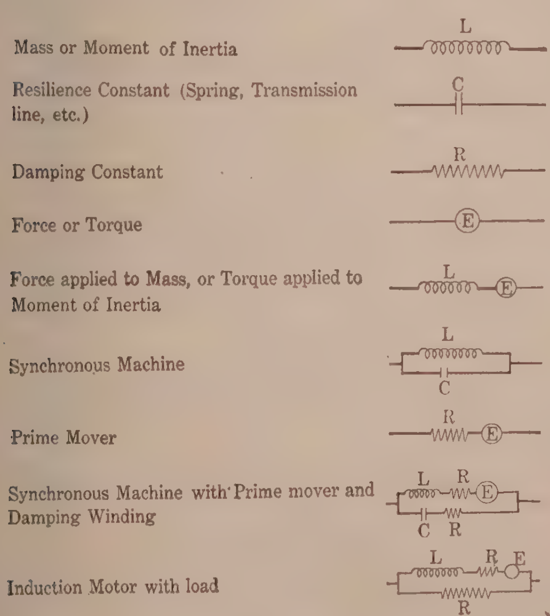


Fig. 5—Equivalent Circuits

Eq. 2, the prime mover torque at any relative speed will be represented in the equivalent circuit by

$$e = E - R\,i \qquad (3)$$

The quantity K, or the slope of the torque speed characteristic, is thus represented in the equivalent circuit by a resistance.

For other gate openings, the slope of the line A and its intercept with the Y axis will have other values. Under actual conditions, the governor will change the gate opening as a certain function of time thus necessitating values of E and R in equation (3) which are also functions of time. An approximate method of obtaining the proper functions for these quantities is illustrated in the representation of the governor given in Appendix A. However, under transient conditions it requires from two to four seconds for the governor to function;

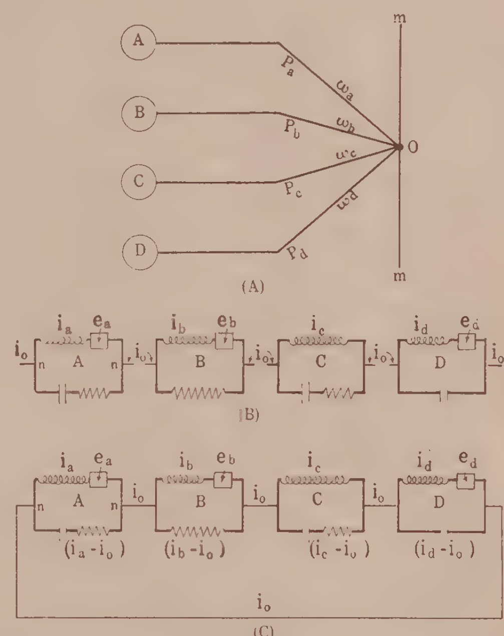


Fig. 6—Synchronous and Induction Machines Connected to the Same Bus

hence, the phenomena may be investigated, at least approximately, during the first second or two under the assumption of constant gate opening.

In all equivalent circuits, the inductances, which are used to represent inertia, possess a certain amount of inherent resistance. This resistance, however, can always be considered as a part of the resistance required to represent the torque-speed characteristic. Oscillograms of voltage across the terminals of the various inductances to obtain inertial forces, will include the small resistance drop due to the inherent resistance of the reactor. To obtain the true inductive voltage it is, of course, only necessary to subtract the resistance voltage at each instant from the total voltage.

The equivalent circuits for the individual elements of the system, such as generators, motors, transmission line, etc., have been established, and are shown in Fig. 5. It is now necessary to show how these must be connected in a combined, equivalent circuit to represent the system as a whole.

Referring to Fig. 6, let any number of synchronous and induction machines A, B, C, etc., including generators, motors and synchronous condensers, be connected

to the bus $m\,m$. The conditions which must be satisfied are:

(1) Σ power flowing *to* point o must equal zero.

(2) The speed ω of all branches must be the same at the point o; being the synchronous speed of the bus.

(3) Therefore, Σ torques, corresponding to the various values of power, and to that speed, must be zero.

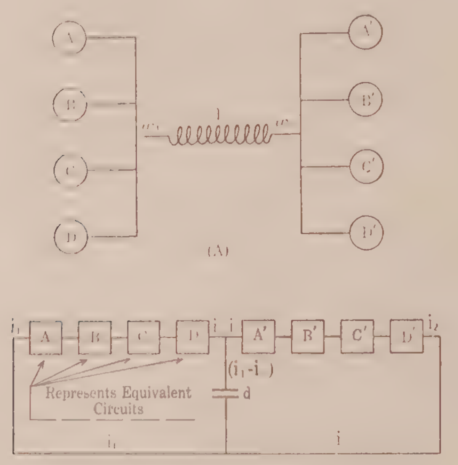


Fig. 7—Equivalent Circuit for Two Busses Connected by a Transmission Line

Thus, by (1),

$$\Sigma\, p = o = p_a + p_b + p_c + p_d + \ldots .$$

By (2)

$$\omega_a = \omega_b = \omega_c = \omega_d \ldots\ldots\ldots = \omega_0$$

By (3)

$$\Sigma\, T = 0$$

Fig. 6B shows the equivalent circuits for the various units A, B, C, etc. The speed of the terminal voltage—that is, the voltage at O Fig. 6A—is represented by the current i_0. Since this must be the same for all units, the circuits must be connected in series; and since Σ torques must equal zero—the torque evidently being the voltage[6] between the junction points $n\,n$—it follows that Σ voltages must equal zero. Hence by Kirchoff's Law, the circuit must be closed, as in Fig. 6C. Therefore, *for any number of machines connected to a bus, as in Fig. 1A, the equivalent circuits of the various units should be connected in series*, as in Fig. 6C.

Thus, if the synchronous generator A were suddenly dropped from the system (by short-circuiting the points $n\,n$), the variation in the speed of the bus voltage, the instantaneous values of phase displacement, torque, speed, slip, etc. of the various machines can be read at once from the currents and voltages of the various branches. This is shown in more detail in the *Numerical Illustrations.*

Next, consider two such busses connected by a transmission line, as in Fig. 7A. The difference between the speeds ω_1 and ω_2 of the two bus voltages is, of course, the rate at which the angular displacement between the two voltages is changing. Thus, in Fig. 7B, if i_1 and i_2 represent respectively those two speeds, then $i_1 - i_2$ would be the current to the condenser, which represents the spring-like characteristic of the line. That is, the charge on the condenser d represents the phase displacement between the ends of the line, and the current $(i_1 - i_2)$ is the rate at which it is changing. The connection must, therefore, be as in Fig. 7B. The rectangles A, B, C and D in Fig. 7B represent the equivalent circuits as shown in Fig. 6B.

Consider next a system as shown in Fig. 8A. At the junction point or bus at G, the speed for all branches is the same, namely ω_2. There must therefore be a main series circuit, which connects the various individual circuits, and in which a current i_2 flows. Yet each bus will likewise have its own series circuit as in Fig. 6. The transmission lines a, b and c will each be represented by a condenser, which takes a current equal to the difference between i_2 and the current representing the speed of the particular bus. Thus, the component circuits are shown separately in Fig. 8B. The connections are completed by inspection, as in Fig. 8C. Thus the series circuit for each bus is shunted by a condenser representing the line which connects that bus to the

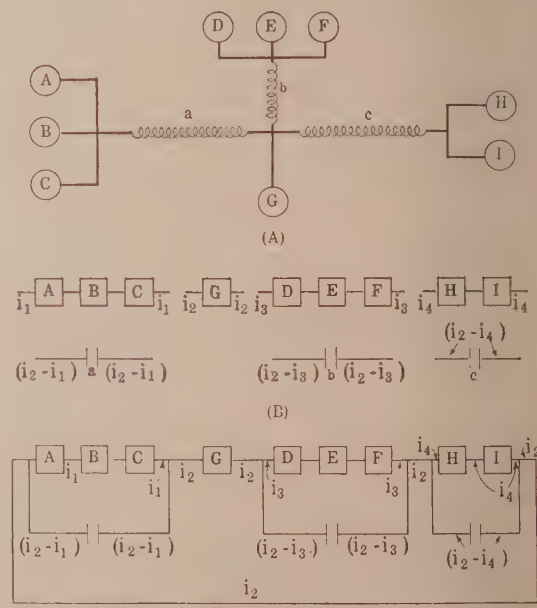


Fig. 8—Equivalent Circuit for a Four-Branch System

6. The voltage $n\,n$ represents the electro-magnetic torque, and is obviously the impressed torque minus that consumed in acceleration:

$$T = T_m - I\,\frac{d\,\omega}{d\,t}\text{; or, in the electrical circuit}$$

$$e_{nn} = e_a - L\,\frac{d\,i_a}{d\,t}.$$

common point at G; and the groups are then all connected in series.

Following the same reasoning, the equivalent circuit for the complicated system in Fig. 9A can be constructed. Here, each circle marked ω represents a bus with any number of units on it, such as in Fig. 6A. From the individual circuits shown in Fig. 9B as sketched from inspection of Fig. 9A, the final connections are made as in Fig. 9C.

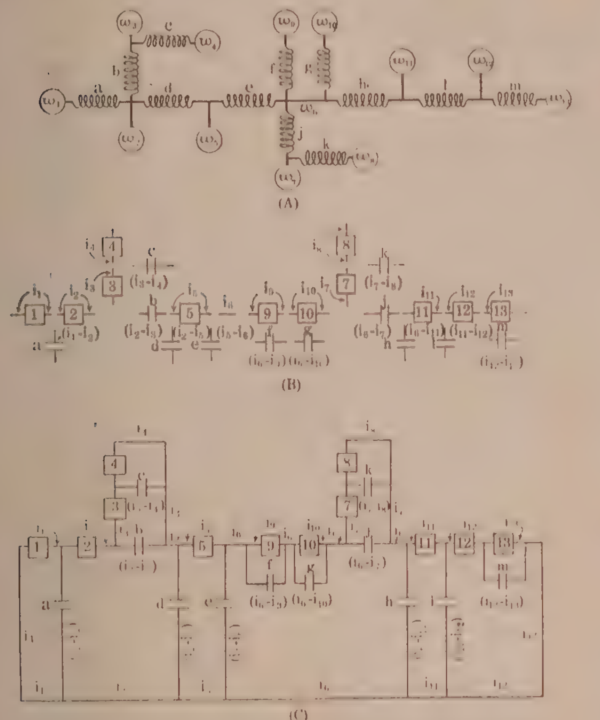


FIG. 9—EQUIVALENT CIRCUIT FOR AN EXTENDED SYSTEM

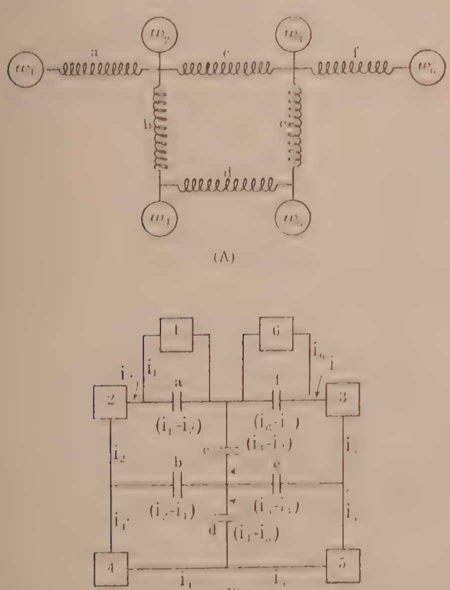
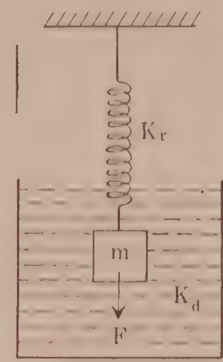


FIG. 10—EQUIVALENT CIRCUIT FOR A CLOSED SYSTEM

Likewise, the equivalent circuit is constructed for the network shown in Fig. 10.

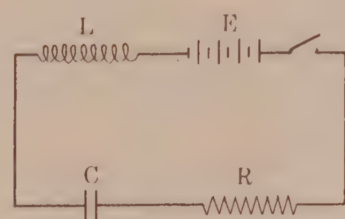
Thus the guiding principles for setting up the equivalent circuits are:

1. For any number of machines connected in parallel to a bus, the equivalent circuits should be connected in series, as in Fig. 6C.



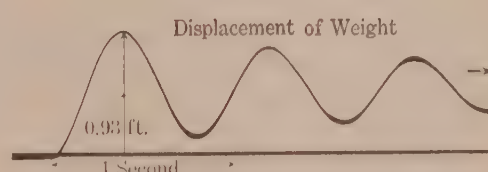
$m = 0.1475$ (4.75 lb.)
$K_r = 0.111$ ft. per lb.
$K_d = 0.116$ lb. per ft. per sec.
$F = 4.53$ lb.

a 1.11
b 0.0407
c 0.0396



$L = 0.164$ henrys
$C = 165\ \mu f$
$R = 3.18$ ohms
$E = 120$ volts

11A



11B

FIG 11—CASE 1.
(A) Equivalent Circuit
(B) Oscillographic Solution

2. If this bus is connected to another through a transmission line, or other inductance (the line or inductance thus being a series connection), the condenser, representing the line, should be connected in shunt as in Fig. 7B.

3. Condensers, representing transmission lines, must be always connected in such a way that the condenser current will be the difference between the two currents,

representing respectively the speeds of the two buses which the line connects.

Numerical Illustrations

The differential equations, shown in connection with Figs. 1 and 2, are set up in terms of actual mechanical speeds and displacements. However, on account of the fact that the actual speeds of the various units comprising the system are different on account of the different numbers of poles, it has been found more convenient, in handling actual numerical examples, to reduce all quantities to the basis of a two-pole machine. This has been done in numerical examples here considered. The conversion factors are given in Table IV, Appendix B.

Case 1. Fig. 11A shows a mechanical system, consisting of a mass and spring suspended from a rigid support, having the mass m constrained to move in a damping bath. The constants of the mechanical system and the available values of L, C, and E for use in the equivalent electrical circuit are given.

The conversion factors are then obtained as follows:

$$a = \frac{\text{inductance}}{\text{mass}} = \frac{0.164}{0.1475} = 1.11$$

$$b^2/a = \frac{\text{capacity}}{\text{resilience constant}} = \frac{165 \times 10^{-6}}{0.111}$$

$$= 0.00149$$

From which

$$b = 0.0407$$

$$\text{also,} \quad \frac{a\,c}{b^2} = \frac{\text{voltage}}{\text{face}} = \frac{120}{4.53} = 26.5$$

Then,

$$c = 26.5\, b^2/a = 0.0396$$

Of the three constants, L, C and R, if two of them are chosen arbitrarily, the third is thereby fixed. Since resistance values are easily obtained, it is convenient to take L and C as are available, and let the resistance be what is thus required.

The conversion factor for the damping constant is

$$\frac{a}{b} = 27.3$$

Therefore,

$$R = \frac{a}{b}\, K_d = 3.18 \text{ ohms.}$$

The oscillogram, Fig. 11B, was taken of the voltage across the condenser, C, for a sudden application of voltage, E, thus giving a measure of the displacement force of the spring. The actual displacement force is obtained by dividing the voltage by its conversion factor, $\frac{a\,c}{b^2}$. The values of time for the actual system are obtained by dividing the time on the oscillogram by the factor b. Therefore, the oscillogram gives the plotted curve of either the actual displacement or the displacement force as functions of time, by merely giving it the proper scales.

Case 2. Fig. 12A shows a composite mechanical system with its equivalent circuit. The constants for the two systems are

Mechanical	Electrical
$m_1 = 0.218$	$L_1 = 0.246$ henrys
$m_2 = 0.1475$	$L_2 = 0.167$ henrys

Mechanical	Electrical
$k_{r1} = 0.131$ ft-lb.	$C_1 = 54.9$ microfarad
$k_{r2} = 0.111$ ft-lb.	$C_2 = 46.5$ microfarad
$F = 2.18$ lb.	$E = 264$ volts

The mass, m_1, was raised to a point 0.286 feet above its normal equilibrium position and then suddenly re-

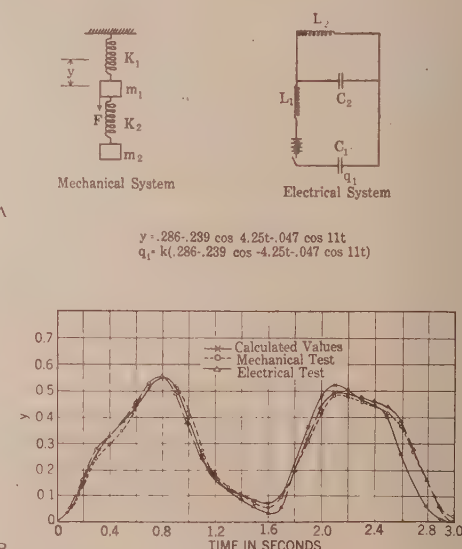


Fig. 12—Case 2

(A) Equivalent circuit

(B) Comparison of mathematical and oscillographic solutions with actual test.

leased. The displacement as a function of time was then calculated mathematically, and also solved by means of the equivalent circuit with the aid of an oscillograph. Actual test was also made on the mechanical system. The results of the three methods, plotted in Fig. 12B show the remarkable agreement between the different methods.

Case 3. Fig. 13A shows a power system and its equivalent circuit. The generating apparatus consists of a shunt motor driven synchronous generator which delivers power over a transmission line to a synchronous motor. The synchronous motor is direct-connected to a (direct-current) shunt generator which furnishes power to a resistance load. The load was suddently thrown on the shunt generator. The consequent vari-

ation of power over the line was calculated mathematically, measured by means of the equivalent circuit, and obtained from actual test.

The constants used in the analysis are:

Power System	Equivalent circuit
$I_1 = I_2 = 2.78$	$L_1 = L_2 = 0.328$ henrys
$\mathfrak{J}_{r1} = \mathfrak{J}_{r2} = 0.00157$ rad/lb. ft.	$C_1 = C_2 = 27.45$ mfd.
$\mathfrak{J}_{d1} = \mathfrak{J}_{d2} = 6.3$ lb. ft/rad/sec.	$R_1{}^1 = R_2{}^1 = 16.4$ ohms
$\mathfrak{J}_r{}^3 = 0.00193$ rad/lb. ft.	$C_3 = 33.6$ mfd.

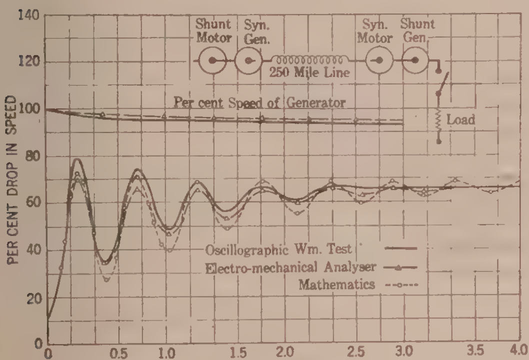


Fig. 13—Case 3

(A) Equivalent circuit
(B) Comparison of mathematical and oscillographic solutions with actual tests.

Shunt motor torque-speed characteristic,

$K_1 = 3.3$ lb. ft/rad/sec. $R_1 = 8.6$ ohms

Shunt generator torque-speed characteristic,

$K_2 = 0.335$ lb. ft/rad/sec. $R_2 = 0.875$ ohms

Applied torque

$\mathfrak{J}_2 = 127$ lb. ft. $E_2 = 130$ volts

I = moment of inertia

$\mathfrak{J}_r$ = resilience constant

$\mathfrak{J}_d$ = damping constant

Subscripts, 1, 2, and 3, refer to sending apparatus, receiving apparatus, and line, respectively.

Case 4. Fig. 14A shows a composite power system and its equivalent circuit. The system is comprised of a waterwheel driven generator, (1) delivering power over a two circuit transmission line to a bus, to which may be connected a turbo-driven generator (2), a synchronous motor (3), and a synchronous generator (4).

Tests were made by means of the equivalent circuit to determine the nature and magnitude of the disturbances in various parts of the system when, (a) a section of the line is opened, and, (b) when synchronous generator, (4), is dropped from the system. Figs. 14B, 14C and 14D show the effect in the various units of dropping a section of line. In the equivalent circuit representing this condition switch (2) is permanently closed and switch (1) is initially open, but is closed to produce the disturbance due to dropping a section. For this condition, the synchronous motor, (3) was assumed to be carrying 400,000-kw. load, generator (1), 120,000 kw; and generator (2), 280,000-kw. Generator (4) is not connected.

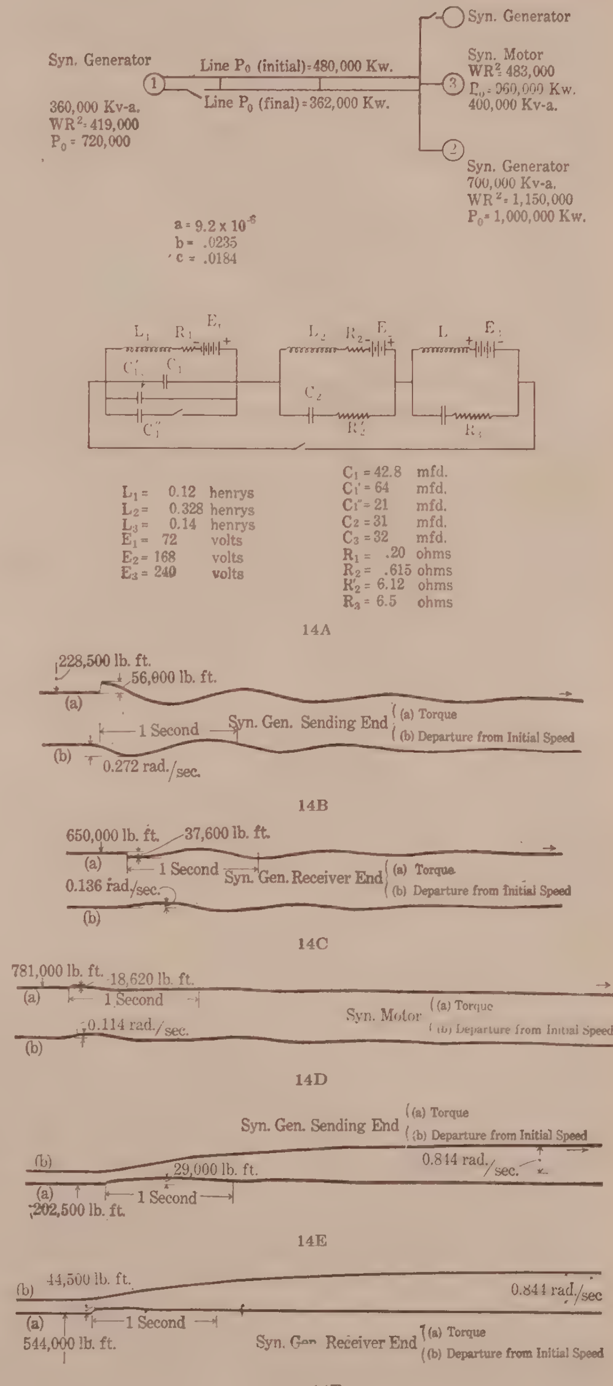


Fig. 14—Case 4

(A) Equivalent circuit
(B), (C), (D), (E) and (F). Oscillographic solutions

Initially the system is running in equilibrium with a resultant distribution of power and displacement angles throughout the system. When the section of

line is dropped, the power-angle characteristics for the system are instantly changed. For the first moment, however, the rotors, due to the inertia, remain in their original relative positions. Therefore, due to the change in power-angle characteristics of the system, there is an instantaneous redistribution and change of power and torque for the various units. Oscillograms (a), Figs. 14B, 14C, and 14D show this instantaneous redistribution and subsequent variations of torque with time for units (1), (2), and (3) respectively.

The final distribution and magnitude of power and torque is the same as the initial distribution and magnitude, since these are determined only by the governor characteristics of the prime movers and the applied load, which remains constant. However, the angular positions of the rotors with respect to each other, are different in the final condition from the initial condition since the power-angle characteristics are different. In changing from the initial to the final positions, the rotors go through certain cyclic changes in speed as shown in oscillograms (b), Figs. 14B, 14C and 14D.

The effect of dropping generator (4) was next investigated. For this condition switch (1), in the equivalent circuit, remains open and switch (2), across which the voltage normally represents the torque of generator (4), is closed, thus eliminating the torque of generator (4) from the system. In this case the synchronous motor (3) is assumed to be carrying a 400,000-kw. load; generator (1), 100,000-kw; generator (2), 280,000-kw; and generator (4), 20,000 kw.

The consequent variations of torque in units (1) and (2) are shown in oscillograms (a), Figs. 14E and 14F, respectively. The final speed of the system is not the same as the initial speed, and the variation of speed in units (1) and (2) are shown in oscillograms (b), Figs. 14E and 14F, respectively.

Case 5. Fig. 15A shows a system consisting of an induction-motor and a shunt-motor-driven synchronous generator connected to the same bus. Fig. 15B shows variation of induction motor slip and synchronous generator torque consequent to suddenly applying full load to the induction motor. The constants shown in Fig. 15A were used in this test. The curves shown in Fig. 15B indicate that the disturbance was slightly oscillatory. To make this more pronounced, the oscillograms in Fig. 15C were taken for an induction motor which would carry full load at ½ of one per cent slip. For this condition, R_2, in the equivalent circuit, was changed to 280 ohms. Oscillogram (b), Fig. 15C shows the speed of the synchronous generator rotor with respect to its terminal voltage and oscillogram (a) shows the torque of the synchronous generator. In this case the disturbance was decidedly oscillatory, thus showing that the combination of an induction motor with a synchronous machine is not necessarily logarithmic.

ACKNOWLEDGMENTS

The author gratefully acknowledges the valuable suggestions of Mr. R. H. Park, Professor V. Karapetoff and Dr. A. R. Stevenson, Jr., also the assistance of Messrs. K. C. Mobarry and L. M. Best, in making tests and preparing the data.

Appendix A

(Suggested by Professor V. Karapetoff)

CENTRIFUGAL GOVERNORS

Due to the inertia and sluggishness of the centrifugal governors controlling the prime movers,—especially the water-wheels, —additional periodic forces may be called into play in the hunting machines, which sometimes aggravate the conditions. For small changes in position, a governor may be assumed to add an input of steam or water proportional to the departure of its actual position from that corresponding to the steady load. Thus, calling this departure x, Arnold's[7] equation for a synchronous machine with an applied torque becomes

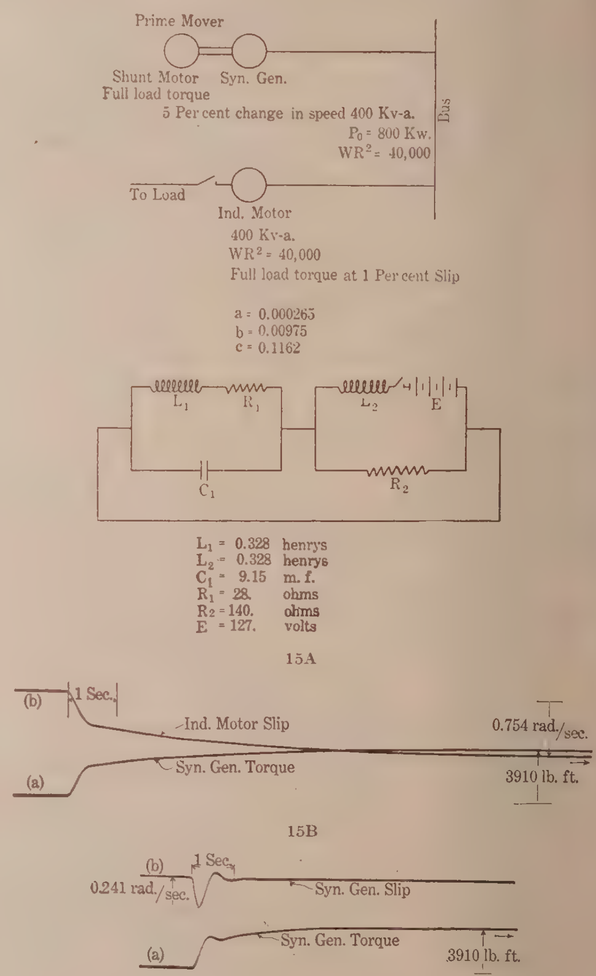


FIG. 15—CASE 5

(A) Equivalent circuit

(B) and (C), Oscillographic solutions

$$(J/p)\,\Omega_m\,(d\omega/dt) + W_s(\theta - \theta_m) + W_d(\omega - \omega_k) = G\,x \quad (1)$$

where G is a coefficient of proportionality, equal to

additional power per unit length of governor displacement[8]. Since the moving part of the governor has some inertia and is subjected both to a restoring force and to friction, its equation of motion is of the form

$$L_g(d^2x/d\,t^2) + r_g(d\,x/d\,t) + s_g x = r_0\omega \qquad (2)$$

In this expression, L_g is the mass of the moving part, r_g the friction factor, and S_g the restoring force per unit displacement. The right-hand side represents the external force, that is, the action of the generating unit, and may be assumed to be proportional to the deviation ω of its instantaneous angular velocity from the mean angular velocity ω_m; r_0 is a coefficient of proportionality. Eq. (2) is identical with Arnold's eq. (289) on p. 410, except that his x represents the total travel of the governor body from the position of zero speed, so that the departure from the mean operating position is denoted by $x - x_0$. The same applies to his value of ω.

Eqs. (1) and (2) are simultaneous differential equations of a generating unit which is hunting and the

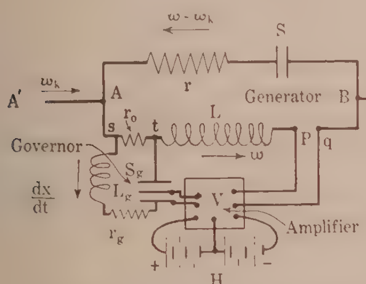


Fig. 16—Equivalent Circuit for Centrifugal Governor

governor of which is also slowly oscillating. Both equations are of the general type,

$$L \frac{d\,i_0}{d\,t} + S\,q + r\,i = E$$

and can be represented by two coupled, equivalent, electric circuits, Fig. 16. This equation is the familiar expression for Kirchoff's second law in a network, around a closed loop containing an inductance L, and elastance S[9], a resistance r, and an external applied e. m. f. E. It must be kept in mind, of course, that in eq. (2), x corresponds to the electric charge q, and that, therefore, the current in the equivalent circuit of the governor is equal to $(d\,x/d\,t)$. The energy transformations in the governor itself are small as compared to those in the alternator, and the governor acts merely as a relay—controlling energy input into the prime mover. Therefore, in the equivalent electric circuit the storage battery H is shown, the energy of which may be added at will between the points P and q, which correspond to the disturbing e. m. f. e_a in Fig. 6c. An amplifier, V, is connected with its input side in the governor circuit and the output side in the alternator circuit.

In eq. (1), the term $G\,x$ on the right-hand side represents the voltage between the points P and q, proportional to the instantaneous displacement of electricity, x, in the governor circuit. For this reason, the input leads to the amplifier are shown connected across part of the condenser S_g. The elastance of this part is so chosen, that the voltage across it, when properly amplified, will give the required voltage, G, on the output side.

In eq. (2), the right-hand side represents the drop of voltage due to the current ω through a resistance r_0. This resistance is shown connected between the points s and t of the inductance branch of the main circuit. Since the currents and the voltages in the governor circuit are much smaller than those in the main generator circuit, the resistance r_0 is of the nature of an ammeter shunt. This means that the voltage drop across $s\,t$ is small in comparison with that across $A\,B$, and the current $d\,x/d\,t$ is small in comparison with ω.

Since the main circuit in Fig. 16 is practically identical with that shown for the individual unit in Fig. 6c, the other connections as shown in Fig. 6c still hold true when some or all of the machines in parallel are controlled by centrifugal governors.

When the action of the gate, controlled by a centrifugal governor, causes a surging motion of the whole column of intake water, the inertia of this column and the elastance of the surge tank may have to be taken into consideration. This can be done by including in the circuit of the battery H, Fig. 16, some inductance, resistance and elastance, connected somewhat like in the equivalent circuit of the generator itself.

Appendix B

Conversion Factors for Reducing Quantities to the Basis of a Two Pole Machine

Since power systems, in general, are comprised of multipolar machines having unequal numbers of poles, the relation between mechanical and electrical speeds for the various units is not uniform. For the sake of uniformity and convenience in numerical examples, it is advantageous to substitute for the respective units an equivalent two pole machine. The synchronous electrical speed of the system then becomes identical with the synchronous mechanical speeds of the various units.

If p is the number of poles of any given unit, the speed of the equivalent two pole machine must be $p/2$ times as great since the the electrical speed or frequency must remain the same.

Also since torque is inversely proportional to speed for a given power, the torque of the equivalent two pole machine will always be $2/p$ times the torque of the actual machine.

Since the speed for the two pole unit is $p/2$ times as great as the actual mechanical speed, it is evident that

7. *Die Wechselstromtechnik*, Vol. 4, Second Edition, page, 381.
8. *Die Wechselstromtechnik*, Vol. 4, second edition (pp. 415 and 418).
9. An elastance is a reciprocal of a capacitance; see V. Karapetoff, "The Electric Circuit," page 148.

the acceleration for the equivalent machine will also be $p/2$ times as great as the actual mechanical acceleration. Now in general, the torque consumed in acceleration is $T = I a$

Or, $$I = \frac{T}{a}$$

where I is the moment of inertia and a the acceleration produced by the torque T. The conversion factor for I is then evidently the ratio of the factor for torque to the factor for acceleration, or $4/p^2$.

The mechanical angle traveled through in a given time will be proportional to the speed or $p/2$ times as great in the equivalent two-pole machine as for the actual unit.

Let P_0 be the power required to produce a displacement of one electrical radian in the synchronous machine. Since the conversion factors are to reduce all quantities to the basis of a two pole machine, and P_0 is already expressed in these terms, the factor for it is unity.

Following the foregoing reasoning, the factor for converting the actual resilience constant,

$$\mathfrak{J}_r = \frac{\text{Mechanical displacement}}{\text{torque required to produce it}}$$

to a two pole basis, is $p^2/4$.

Likewise the factor for converting the damping constant $\mathfrak{J}_d$, is $4/p^2$.

The conversion factors are tabulated in Table IV.

TABLE IV

Quantity for Actual Machine		×	Conversion Factor	=	Quantity for Equivalent two-pole machine
Mechanical torque	$\mathfrak{J}$		$2/p$		
Mechanical angle	θ		$p/2$		
Moment of inertia	I		$4/p^2$		
Mechanical resilience constant	$\mathfrak{J}_r$		$p^2/4$		
Mechanical damping constant	$\mathfrak{J}_d$		$4/p^2$		
Mechanical angular velocity	ω_m		$p/2$		
Kw. per elec. radian	P_0		1		

The Relation Between Engineering Education and Research, with Particular Reference to the California Institute of Technology Plan

BY R. W. SORENSEN[1]

Fellow, A. I. E. E.

RESEARCH and engineering are inseparable, therefore, research must be a part of engineering education. This fundamental fact has been eclipsed during the first quarter of the present century by practical influences of major importance. These influences are the awakening of the engineering profession to the fact that much of the advancement in engineering knowledge has been made at the expense of the general culture of the members of the profession, the demand for men to occupy a large number of subordinate engineering positions, and the addition of new engineering knowledge which must be included in an engineering course.

The engineering profession first took definite form when in 1828 the Institute of Civil Engineers wrote in their charter the following words:

"Art of directing the great sources of power and nature for the use and convenience of man, as the means of production, and of traffic in states, both for external and internal trade, as applied in the construction of roads, bridges, aqueducts, canals, river navigation and docks for internal intercourse and exchange, and in the construction of ports, harbors, moles, breakwaters, lighthouses, and in the art of navigation by artificial power for the purposes of commerce, and in the construction and adaption of machinery and in the drainage of cities and towns."

1. Of the California Institute of Technology, Pasadena, Calif.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

To train men for this work, technical colleges were established and laboratories for experimentation were provided. From the establishment of the engineering profession until the opening of the present century, engineering books were few in number and the material included therein was very meager as compared to that of the present time. Under this condition, the student was compelled to make his own text by listening to lectures, reading technical articles, and trying out experiments, all of which work was more or less in the nature of research.

As the list of completed experiments grew, the results took form and appeared in texts as material which an engineering student must know. As a result more and more time was devoted to learning proven fundamental technical facts; the undergraduate laboratory work became of necessity of the "cook-book type," all of which left less time available to students for new, and non-technical work.

A pretense of keeping economics and English in engineering courses has been made; these subjects have been given in tabloid form, the "dose" being gradually reduced with the result that engineers as a group have become known as intellectual machines, capable of doing the world's work, but in many ways quite unfitted for the higher positions of our social structure

through their handicap in making contact with the non-technical members of the human family.

To remedy this defect, English, history, economics, etc., are being returned to the curriculum of our better engineering colleges, and the last vestige of undergraduate research, the senior thesis, has been crowded out. Also, the demand for men with engineering training has caused many younger men with no desire or aptitude for research or invention to successfully complete engineering courses and enter the engineering profession. The majority of these men and also, unfortunately, a considerable number who show research qualifications during the time they are college students, embark after graduation upon a commercial career which may or may not be related to engineering, the reason being the apparent better average remuneration men receive for commercial as compared with technical service.

The undergraduate thesis, as it was handled during the first quarter of this century, was in many cases as useless as the vermiform appendix. It was therefore wisely eliminated. But we should not forget that the thesis is symbolical of research, a function which must be the keystone of engineering education if the engineer is to occupy the place for which he has ambitions.

If research and engineering education are inseparable, a way must be found to include the former subject, in engineering curricula. Apparently this can be done only by extending the time required for engineering courses. Some of our colleges have made this extension by adding a year as a post graduate term; others have made it by changing to a five-year course. The latter plan was adopted last year by the California Institute of Technology.

With the introduction of this plan every new student is required to take entrance examinations and submit a record of work done previously. He is also required to furnish a certificate of good health as evidenced by a thorough physical examination, such as given by life insurance companies and many industrial organizations. This procedure immediately resulted in a decrease in the freshman class to 114 as compared with the maximum allowable number (160) which entered each of the two years preceding. The record of last year's entering class shows several striking facts; the first being a much higher degree of physical efficiency than the preceding class—the only one for which a complete physical efficiency record was available. Another noticeable feature was the small "casualty" list at the end of the first term, there being in this class only five failures at this time; before this system was inaugurated the casualty list included approximately 25 per cent of the class, although 15 recommended high school units have always been required for entrance.

To determine the motives influencing the students at the Institute, 350 copies of a questionnaire, including the following questions, were passed out at the beginning of an assembly period, and the answers collected as the men left the hall. In all, 310 papers were collected, 288 of which could be properly grouped and classified as shown in Table A, composed from the questions following:

Class Age Course

Why did you come to college?

a. Because of the advice of others.
b. Because of interest in ....
c. To enable me to earn better wages.
d. Any other reason..........................

Why did you choose C. I. T.?

Why did you select the course you have registered for?

Are you interested primarily in its

a. Commercial application.
b. Design or construction.
c. Research.
d. Teaching.

Has your work so far been of the character you expected?

If not, how has it differed from that expectation?

What are you planning to do after obtaining the B. S. degree?

Have you changed (1) courses, (2) plans since entering college?

Have you done any practical work relating to the course you are taking?

TABLE A

	Senior	Junior	Soph.	Fresh.	Total
Number of replies received....	47	80	77	84	288
Why did you come to college?					
Because of advice of others	20	37	33	25	115
Special interest..........	35	64	60	65	224
To increase earning power.	26	42	53	56	177
Other reasons............	19	34	28	29	110
Why a particular course was selected:					
Interest in that work.....	32	65	57	59	213
Opportunity.............	11	10	13	10	44
Why C. I. T. was chosen:					
Reputation of college or faculty members.......	30	60	40	46	176
Plan of courses...........	13	19	24	28	84
Location (financial)......	19	25	19	19	82
Occupational intent:					
Commercial.............	36	51	50	50	187
Design or Construction...	18	41	29	41	129
Research................	7	18	20	21	56
Teaching................	3	8	11	3	25
Plans after securing a B. S. degree:					
Continue in college.......	2	7	18	23	50
Work..................	41	55	41	41	178
Undetermined...........	4	6	6	13	29
Number having had practical work related to course of study selected.........	28	48	37	20	133
Number without such work................	19	28	37	52	136
Number who have changed courses................	17	26	30	7	80
Number who have changed life plans..............	13	18	23	18	72

At California Institute of Technology, an endeavor is being made to solve the problem of training technical men with a research spirit. At the present time there are over fifty graduate students and research men conducting researches in physics, chemistry, and mathematics. Also for several years, research in aeronautics and other fields of engineering has been conducted in a limited way, but lack of funds has made it impossible to get equipment and personnel to do all that should be done in these fields. This condition has in all probability been a blessing in disguise, since

the establishment of engineering research stations not properly supported upon a well fabricated foundation of fundamental sciences, mathematics, physics, and chemistry, would be like the erection of handsome buildings without due regard for the unity of the structure,—a procedure which appears all right until tested by a seismological disturbance such as the recent Santa Barbara disaster. Also, had funds been available for a complete development of both pure science and engineering research at one time, there would have been the danger of extravagance which always attends a too rapid development.

Supplementing the physical and chemical research facilities, the Institute now has the 1,000,000-volt laboratory erected on the campus by the Southern California Edison Company; there is also just being completed an engineering research building for research work involving non-electrical engineering problems. This plant will be in charge of the best research engineer obtainable. There will immediately be erected a seismological laboratory for the use of the newly established department of geology.

This detailed description has been necessary because it is a fundamental part of the Institute's plan of education for undergraduate as well as graduate students. The benefit to graduate students is obvious as it is expected that much of their work will be research, to be reported upon by a thesis. In this work there is a certain amount of contact with industry through the way some of the problems originate, the entire financing of the investigation in some cases being undertaken by a commercial organization. In the case of the Edison 1,000,000-volt laboratory there is always a considerable amount of work being done by Edison employees.

The undergraduate is put in contact with this type of work in the following manner: All fifth year men, who are actually the undergraduate seniors, will have work of a research character, though it may not take the form of a thesis in the final report. Beginning with the freshman year, the classes are sectioned according to ability to the extent of placing in honor sections the men who have earned that distinction by virtue of high scholarship. The members of the honor sections are allowed certain privileges, such as the omission of some standardized laboratory work, or fewer hours attendance at regular classes. The time thus gained, honor men are permitted to use in taking advanced or special courses, or in assisting the research men with the work they are doing.

The number of men required to do engineering work who should be given special training beyond that included in the regular undergraduate courses is perhaps an unknown quantity, but at the present there is certainly a shortage of men for important engineering positions. It is one purpose of this paper to prophesy that the men who will best fill these positions in the engineering field during the next quarter century will be those men who spend more than four years in preparation at a good engineering college where provision is made for training in research work.

RADIO USES OF PIEZO-ELECTRIC CRYSTALS

Piezo-electricity is a phenomenon which has been known for many years but which is having some remarkable new applications. Certain crystals undergo a slight expansion or contraction when an electrical voltage is applied to them and, vice versa, produce a slight voltage when compressed or pulled. A piece of quartz crystal 1 or 2 inches long has a high natural frequency of the same order as the frequencies of currents used in radio communication. It has been found that the frequency of vibration of the piece of quartz is extraordinarily constant and that it is very useful as a radio standard. In association with a small electron tube it acts as an oscillator or generator of a current the frequency of which is that of mechanical vibration of the piece of crystal. As the frequency thus produced is accompanied by numerous harmonics, the crystal is a standard giving several radio-frequencies. It is thus a remarkable supplement to the wave meters which have hitherto been used as standards of radio-frequency.

A study just completed by the Bureau of Standards indicates that such a quartz oscillator has many valuable applications in radio work. Means of producing audio as well as radio-frequencies were worked out. The crystals can be used to control or determine the frequency of a transmitting station and to hold it strictly constant, which will mean a great advance in radio-transmission technique. The crystals are also useful in accurate setting of receiving apparatus and in controlling the frequency of radio-frequency generators used in laboratory measurement work. The value of these various applications is particularly great at the frequencies above 2000 kilocycles which are now rapidly coming into use. A preliminary paper on this work has been prepared and will appear in the *Proceedings* of the Institute of Radio Engineers.

Part of the work resulted in the design of an outfit for use by the Department of Commerce radio inspectors and adapted to the rapid and accurate standardization of frequency meters. It consists of two instruments, both being simple devices of low power operated by dry batteries. Persons desiring to construct or procure these instruments can secure copies of specifications therefor from the Bureau of Standards. These specifications are Specifications for Portable Piezo Oscillator, Type N, and Specifications for Portable Auxiliary Generator, Type O. The Bureau has also prepared a set of directions for the use of the two instruments, Letter Circular 183, Directions for Use of the Piezo Oscillator and Auxiliary Generator for Calibration of a Radio-Frequency Meter. It may be obtained upon application addressed to the Bureau of Standards, Washington, D. C., by persons having actual use for it.

Steam-Power in Its Relation to the Development of Water-Power

BY RICHARD C. POWELL[1]

Associate, A. I. E. E.

Synopsis.—*The purpose of this paper is to draw attention to the desirability of the development of our water-power resources on a comprehensive economic basis and to discuss more particularly some of the features of steam-power in connection with the economic development of water-power.*

The limitations of the cost curves frequently used in comparing the costs of water- and steam-power are pointed out and a simple method is given whereby the minimum cost of power may be found for an assumed water-power development with auxiliary steam power.

Some data for a practical case on a large scale are given in order to show just what the use of auxiliary steam-power may mean in the reduction of capital expenditures and generating costs.

It is a simple economic fact that the value of an article which has reasonable life and which can be reproduced in quantity is determined not by the costs of the article itself, but by the costs of the same article manufactured subsequently. And, furthermore, the cost of a substitute finally determines the value for the article when no longer capable of successive reproduction. Economically considered, water-power is an article of interminable life apparently capable of successive reproduction in the form of the development of new sites, but in reality an article of limited availability whose value must finally rest upon that of some substitute.

The extent of development of a given site for much of the existing water-power was determined by financial limitations which required a minimum first cost. The electric light and power industry today, however, is on the whole no longer forced to uneconomic practises on account of inability to finance properly. In other words, the industry stands upon a free economic basis, and, hence, an economic study of any given water-power project should include the costs of the next probable developments. It is evident, therefore, that most projects will on this basis be developed to a somewhat greater extent than if considered alone, for developments will naturally be selected in the order of cheapness. Carrying this idea to a conclusion, we are forced to a consideration of the last available water-power, which can be economically developed and finally to some other form of power, which is undoubtedly that to be obtained from burning fuel, which, at the present time, is steam-power.

Various estimates have been made as to the time when there will remain but little undeveloped water-power in the United States. An estimate published recently puts it at ten years for the Eastern States and twenty for those on the Pacific Coast. At any rate the end of the undeveloped water-power is in sight, and economic studies should be made for the remaining water-power as a whole. In our water-power we have a limited natural resource of great value but costly to develop. Dams, tunnels, etc., are expensive and not readily changed and it is, therefore, most important that studies include probable future conditions. It is not the purpose to discuss at length this feature of the relation of steam-power to the development of water-power. But, it is desirable to call attention to the economic possibilities in the proper employment of steam-power in conjunction with water-power to the end that economic studies for the development of water-power will include consideration of steam-power.

The preceding merely touches upon one aspect of the subject. Another is that presented by the opposite cost characteristics of water- and steam-powers, viz: high fixed charges and low operating costs for the one and low fixed charges and high operating costs for the other. Another is that brought up by variable stream flow, not only varying from month to month, but from year to year, and the fact that the variations in stream flow do not in general follow the load variations, that is, stream flow and load characteristics are dissimilar.

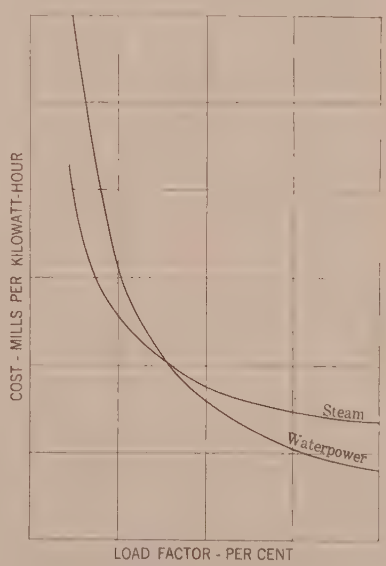


FIG. 1—TYPICAL COST CURVES FOR STEAM- AND WATER-POWER

The usual method of comparing the costs of water- and steam-powers is by means of curves similar to those

1. Of the Pacific Gas & Electric Company, San Francisco, Cal.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

shown in Fig. 1. The annual cost of water-power is c dollars per kilowatt delivered to the load center and, hence, the cost of water-power per kilowatt-hour is

$$W = \frac{C}{8760\, f} \tag{1}$$

where f is the use factor.

Similarly the cost of steam power per kilowatt-hour is

$$S = \frac{a}{8760\, f} + b \tag{2}$$

where, a = (fixed charges on the investment) + (The cost of operation and maintenance) + (the cost of fuel to keep the plant hot with turbines turning over and operation of the auxiliaries), all as annual costs per kilowatt of station capacity, and,

b = the fuel cost per kilowatt-hour

The relation between fuel and kilowatt-hour output for a steam plant is linear as shown in Fig. 2. The line $A\ B$ gives the fuel for the net kilowatt-hour output.

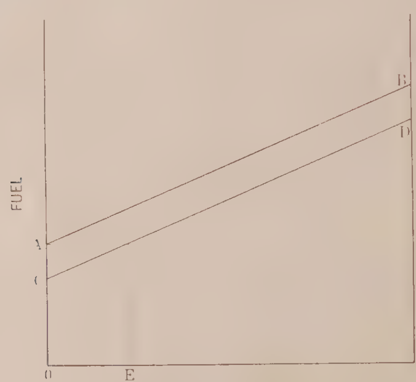


Fig. 2—Characteristic Relation between Fuel and Output for a Steam Plant

For a plant using $O\ E$ kilowatt-hours for the auxiliaries, the line $C\ D$ gives the fuel for the gross output. $O\ A$ is the fuel which enters into the term a and b is the slope of the line, either $A\ B$ or $C\ D$.

It is apparent from the curves in Fig. 1, that, in general, water-power gives lower cost for high load factors while steam has the advantage for low load factors. It must be noted, however, that the cost curve for steam-power is correct for all load conditions while that for water-power is not. In general, this cost curve for water-power does not show the relation between cost per kilowatt-hour and load factor, but that between cost per kilowatt-hour and output. Unless the output as a function of time (output curve) coincides with the load as a function of time (load curve), this cost curve is not correct. The conditions for correctness are:

1. A constant stream flow.
2. A varying stream flow with flow curve similar to the load curve.
3. A regulated stream flow.

Of these three cases, (1) is very rare, Niagara being an example, (2) is not known to exist while (3) is not unusual.

It is very seldom that water-power can be developed at such a low cost that some steam-power will not lower the costs of generation. An exception is the case of a reasonable cost water-power of constant stream flow or a regulated flow plant supplying a load having a load factor approaching 100 per cent. The reason for the ability of steam-power to reduce the cost of generation is quite clear when one considers that (1) the load may

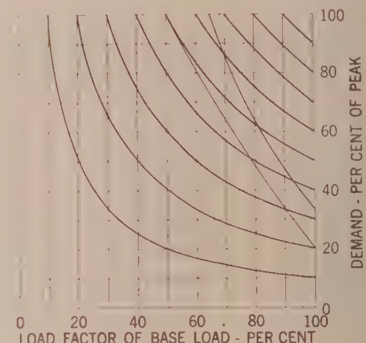


Fig. 3—Relation between Load Factor and Demand for Base Load

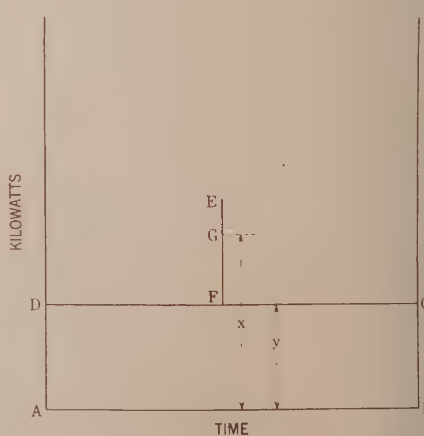


Fig. 4—Load Curve to Explain Theory of Chart, Fig. 3

be split into two parts by taking off a given percentage of the peak, one part being the so-called "base" load and the other the "peak" load and that (2) the load factor of the base load may be anything from 100 per cent to that of the total load, and the load factor of the peak may be anything from zero to that of the total load. And further, that by proper division of the total load and with the base load on water-power and the peak on steam, a minimum cost for power will result.

If p be the proportion of the peak taken on steam, $1 - p$ will be the proportion of peak of the base load on water-power. Let q be the proportion of the kilowatt-

hours taken on steam. Then the cost of power per kilowatt-hour is, by combining equations (**1**) and (**2**)

$$p = \frac{c\,(1 - p) + a\,p + 8760\,f\,q\,b}{8760\,f}$$

Reducing and putting k for $8760\,f$, that is, the kilowatt-hours delivered per kilowatt of demand,

$$p = \frac{c}{K} - \frac{(c - a)\,p}{K} + b\,q \qquad (3)$$

This equation is simple and all that is needed to make it workable is a relation between p and q. This can be done with a fair degree of accuracy with the chart shown in Fig. 3. All that it is necessary to know is the peak load, minimum load and the load factor. The theory of this chart will be clear by referring to Fig. 4. Assume a load curve of the shape $A\ B\ C\ F\ E\ D$ having a portion $E\ F$ representing an instantaneous peak without kilowatt-hours. If a portion of the peak is taken off such as $E\ G$ then the load factor of the base load will change but not the kilowatt-hours. Hence, if the percentage of the peak for the line $C\ D$ is y and that for

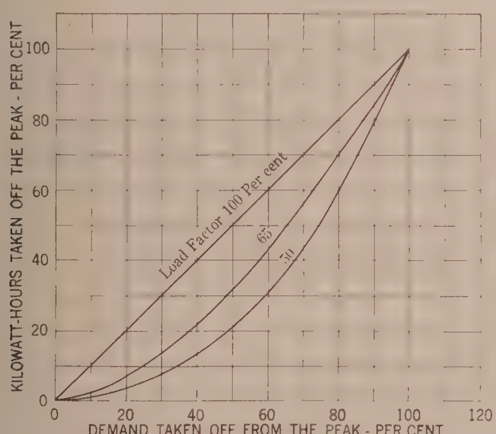


FIG. 5—RELATION BETWEEN PEAK AND KW-HR., TAKEN FROM A LOAD CURVE BY TAKING OFF A PORTION OF THE PEAK

the point G is x then the load factor of the load with a peak G is given by

$$f - \frac{y}{x}$$

The series of curves in Fig. 3 is plotted from this equation. Since an actual load curve must increase in kilowatt-hours as the percentage of the peak is increased, it follows that in tracing on this diagram the curve of relation between load factor and peak for the base load, such a curve must continually cut the curves of the diagram. Once having this curve for the base load, the kilowatt-hours for the peak load remaining together with the percentage of these kilowatt-hours to the total load is readily obtained. If the curve traced is not approximately correct this will be apparent on the curve plotted to show the relation between p and q in equation (**3**).

In Fig. 3 are shown two traces for loads of 65 and 50 per cent load factors and minimum loads of 33 and 20 per cent respectively. The corresponding $p\,q$ curves are given in Fig. 5.

With equation (**3**) and the assistance of the $p\,q$

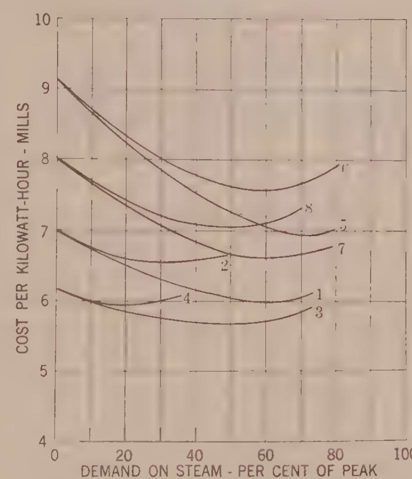


FIG. 6—VARIATION OF POWER COST WITH COST OF WATER-POWER, FUEL AND LOAD FACTOR

Curve Number	Cost: Water-Power Dollars per year per kw. demand	Cost: Fuel per bbl.	Load Factor
1	40	1.50	65
2	40	2.00	65
3	35	1.50	65
4	35	2.00	65
5	40	1.50	50
6	40	2.00	50
7	35	1.50	50
8	35	2.00	50

curves the values for plotting the curves of Fig. 6 were calculated. These curves are given to show in a general way, how the cost of power is affected by variations in the costs of water-power and fuel. For the cost of steam-power, the following conditions are assumed; oil as the fuel and at full load a kilowatt-hour for 15,000 B. t. u.; steam plant costing \$90.00 per kw.; standby fuel 2.5 bbl. per kw. per year and output at 450 kw-hr. per bbl.; operation and maintenance at \$3.50 per kw. per year. The cost of water-power is taken at \$35.00 and \$40.00 per year per kilowatt of output.

It is readily seen that the conditions favorable to a minimum of steam are low cost hydro development, high fuel cost and high load factor. With a 65 per cent load factor which is higher than that of most systems, with oil at \$2.00 per bbl. which corresponds to coal at about \$8.00 per ton, and with water-power at \$35.00 per year per kw. of output, the minimum cost of power is obtained when 20 per cent of the peak is carried on steam. In this case the cost of generation is reduced

3 per cent as against the case with no steam power. For the same assumed costs and a system load factor of 50 per cent the minimum cost of power obtains when steam carries 50 per cent of the peak and in this case the cost of generation is reduced over 13 per cent as against all water-power.

More important, however, than the reduction in unit generating cost is the reduction in capital required for generating and transmitting facilities. In the case of 20 per cent steam-power under the conditions assumed, only 80 per cent of the capital is required as for an all water-power generation, 10 per cent reserve capacity assumed in both cases. And in the case of 50 per cent steam-power, the corresponding capital amount is reduced to 60 per cent.

In general, the preceding equations and curves cannot be applied directly in actual practise because most systems will have some plants where storage is expensive or not feasible and the output will, therefore, vary according to stream flow. Furthermore, the available hydro kilowatt-hours may be less than the amount presupposed by the curves. This will be apparent from the following example. In Fig. 7 is the graph of the combined monthly kilowatt-hour output for a number of existing and projected water power plants, some of which have flow regulation. The "mean year output" curve is the average monthly kilowatt-hour output for the year for which records are available, and the "dry year output" curve is that for the dryest year to date. The peak output is 575,000 kw., with an annual delivery of 3600 million kw-hr. costing $35.00 per year per kw. of generator demand. If the load factor is

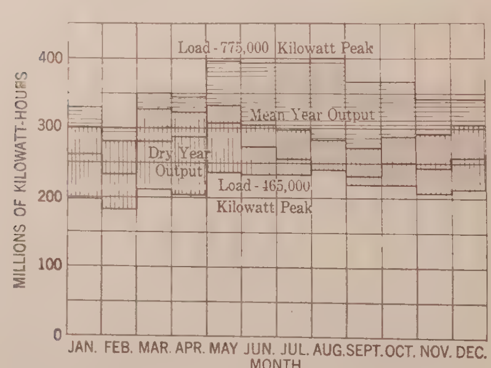


Fig. 7—Kilowatt-Hour Load and Water-Power Output Curves

taken as 65 per cent and oil at $2.00 per bbl. the curves give a minimum cost of generation of 6 mills for 20 per cent of the peak on steam. However, the curves are based upon a delivery factor for the hydro of 75 per cent, whereas from the data just mentioned, this factor for the hydro of 75 per cent, whereas from the data just mentioned this factor is only 71.5 per cent. Furthermore, instead of generating 310 million kw-hr. by steam as shown from the curves, actually 500 million kw-hr. must be carried by steam. It is evident, therefore, that while the cost curves discussed above may be useful in many cases, they are not general and must be used with discrimination.

Referring again to the system output shown in Fig. 7, if no steam-power is employed, the system load which can be carried will be limited by the kilowatt-hour output for the month of August in a dry year. The limiting load will be that having a system peak of

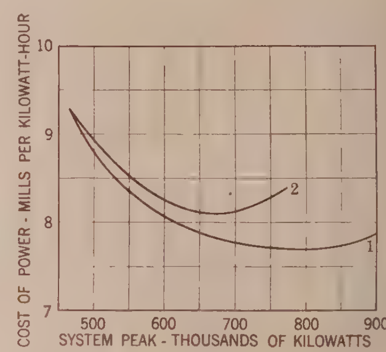


Fig. 8—Variation of Power Cost for Various Loads. Cost of Fuel, $2.00 per bbl. for Curve No. 1 and $3.00 per bbl. for Curve No. 2

465,000 kw. and is shown in Fig. 7. If a system peak greater than this is taken, steam-power will be required to make up the deficiencies in peak and kilowatt-hours. By taking a number of assumed peaks, the required size of steam plant and number of kilowatt-hours generated by steam are easily found. The total costs of generation may then be readily determined and a curve or tabulation will show the load that should be carried for minimum generating cost. The process is simple and requires no further explanation.

The load curve for a peak of 775,000 kw. is also shown in Fig. 7. It is now easily seen from the figure why the use of steam-power reduces the cost of generation. With no steam-power, the kilowatt-hours represented by vertical cross-hatched area between the "mean year output" curve and the "load, 465,000-kw., peak" curve cannot be used because the load will not absorb them. When steam kilowatt-hours represented by the horizontal cross-hatched area between the first mentioned curve and some given load curve which in Fig. 7 is taken for a peak of 775,000 kw., then 1000 million kw-hr. from water power become available by the generation of 720 million kw-hr. by steam, or for the cost of 720 million kw-hr. by steam 1720 million kw-hr. are obtained.

The final result is shown in the curves of Fig. 8, one for oil at $2.00 per bbl. which is reasonably high, and the other for an extremely high price for oil of $3.00 per bbl.

The minimum costs occur for system peaks of 800,000

kw. and 675,000 kw. with oil at $2.00 and $3.00 per bbl. respectively and the corresponding steam plant capacities are 325,000 kw. and 200,000 kw.

The application of steam power to this particular water power development effects the following economies, assuming oil at $2.00 per bbl.

1. Reduces the cost of generation 1.5 mills per kw-hr. or 17 per cent.

2. Reduces the investment 15 per cent or 35 million dollars for the load of 800,000 kw.

This covers the minimum cost for a given assumed development of a group of water-power sites. The absolute minimum will of course be obtained only by an extended study involving the costs for a number of assumed hydro outputs.

The price of fuel will undoubtedly increase continuously to higher levels. This situation will permit an automatic adjustment of the economic ratio of steam-to water-power. For if the price of fuel increases while the cost of water-power additions are not materially increased, the ratio is lowered by discontinuing additions to the steam plants. Referring to Fig. 8 it is seen that for an increase of 50 per cent in the cost of fuel the economic ratio is reduced from 40 per cent to 30 per cent and the 325,000 kw. steam capacity for a load of 800,000 kw. will now be sufficient for a load of 1,100,000 kw. provided the cost of the additional water-power capacity is not greater than that for the existing water-power. Thus, the probable increase in fuel costs contributes in every way to the stability of water-power development and makes its economic development sounder from the financial standpoint. Nevertheless, with the increasing value of fuel, it may be safe to say that steam plants of high efficiency should be constructed.

To summarize the preceding: The development of our water-power should be along comprehensive lines involving in every case studies of other available water-powers and the economic place of steam-power; the usual cost curves for steam- and water-power apply in practise to special cases only and extended studies are required in order to arrive at the economic development of water-power and the economic ratio of steam-power; the employment of steam-power will in most cases lower the cost of generation and reduce appreciably the capital expenditures; and finally the consideration of steam-power as an economic factor in the development of water-power will undoubtedly postpone beyond the time of some recent estimates the construction of the last water-power plant.

ELECTROMAGNETIC LAWS

About sixty years ago, Professor Clark Maxwell, propounded the conception that specific inductive capacity is a quality of the nature of elasticity and that permeability is of the nature of density. This is the generally accepted view of the present day.

In 1900, Prof. Reginald A. Fessenden propounded an opposite proposition; he assumed that specific inductive capacity is a quality of the nature of density, and permeability is of the nature of elasticity. He showed that if Maxwell's conception were true, then the capacity of a condenser ought to be a function of the voltage gradient applied to that condenser; he also showed that if his own conception was true, reluctivity should be a simple linear function of the magnetizing force. In other words, if Fessenden's conception is correct, Kennelly's law should be the true law of magnetization, and, conversely, if Kennelly's law be the true law of magnetization, then the Maxwellian conception must be incorrect, and the magnetic phenomena are really static, the so-called electrostatic phenomena being really dynamic. (*Physical Review:* 1900 p. 1-33, 83-115).

Thus we find ourselves in what seems to be an absurd situation; we accept the Maxwell electrodynamic conception of magnetism, reject Fessenden's conception, and yet accept Kennelly's law, which is incompatible with Maxwell's conception, and a necessary logical consequence of Fessenden's theory. We cannot get out of the difficulty by merely ignoring it; it is a question which should be the subject of further research.

According to Professor Fessenden, the verification of Kennelly's law, by its agreement with the observation curves, constitutes a conclusive evidence of his static conception of magnetism, and an equally conclusive refutation of Maxwell's dynamic conception. But is Kennelly's law the true law of electromagnetic relationship for ferromagnetic material? The experiments of Professor J. D. Ball (*G. E. Review* 1916) are generally regarded as a conclusive evidence in its favor. On the contrary the authors own experiments have led to opposite conclusions. He has found that all permeability curves contain certain peculiarities incompatible with Kennelly's law. The author has not been able to publish his findings until now, but his records, curves and methods of test are open to anyone who is interested in the problem. The question is a very important one and it is hoped that it will have serious consideration.

S. L. Gokhale

Electrical operation of the Virginian Railway between Mullens, W. Va. and Princeton, Va. is proving so satisfactory that plans are now being made to extend this electrification eastward to Roanoke, a distance of 134 route miles. This change will involve the expenditure of $15,000,000.

The Arctic Ocean is now in daily touch with civilization through the most northerly Canadian commercial radio station just opened at Aklavik at the mouth of the Mackenzie River, 125 miles north of the Arctic Circle. It is expected this station will be of great benefit to the residents of the Mackenzie basin.

The Long Span Across The Narrows at Tacoma

BY J. V. GONGWER[1] and A. F. DARLAND[1]

Non-Member Associate, A. I. E. E.

THE double transmission lines now being built by the City of Tacoma, as part of its new Cushman Power Development, connecting Power House No. 1 and No. 2, (future) with the Cushman Substation in Tacoma, reaches 44 mi. from the North Fork of the Skokomish River in the foot hills of the Olympic Mountains around Hood Canal, across North and Henderson Bays and over The Narrows to Tacoma.

The crossings at North and Henderson Bays are over shallow water, permitting of the installation of off shore towers, thereby materially reducing the length of spans that would otherwise have been necessary at these two crossings. Plans and profiles of the crossings at North and Henderson Bays showing the length of spans, and the general features of the design are demonstrated herein.

Over The Narrows is being constructed what is believed to be the longest aerial span in the world, for the purpose of the transmission of electrical energy. The Narrows is a channel approximately 4800 ft. wide from shore to shore, 40 fathoms deep at the point of greatest depth, with a bottom strewn with large rocks. The entire tide run of lower Puget Sound must pass through this restricted channel, the current attaining a velocity of approximately 10 mi. per hour.

The use of submarine cable was never seriously considered for the crossing of The Narrows because of the danger of injury to cable by abrasion over the rocky bottom in the current of the ever changing tide, and further, because it would have been necessary to locate a step-down transformer station on the west side of The Narrows to reduce the line voltage from 110 kv. to a voltage at which submarine transmission can reasonably be expected to offer dependable service, at present probably not in excess of 50 kv. Both the initial and operating costs for the submarine crossing would be considerably in excess of those items for an aerial span.

An all-land line, avoiding the crossing of The Narrows, would, of necessity, have skirted the radial waterways of lower Puget Sound by way of Shelton and Olympia, a distance of 64 mi.; 20 mi. longer than by the line of way of The Narrows, and through a district where a transmission line right-of-way would have been considerably more costly.

The natural conditions at The Narrows are very favorable for an aerial span, there being a high bluff on both sides of good bearing soil on which to locate supporting towers and cable anchorages, although the high ground is well back from the water's edge, requiring a single span of 6241 ft. 6 in. in order to take advantage of the tower sites.

Choice of Conductor

The strength, size and electrical characteristics of the conductor used are, to a large degree, the determining factors in the supporting tower and anchor design and considerable study was given to it's choice.

Three general types of conductor cables were considered, viz:—All steel, steel core with an aluminum envelope, and steel core with a copper envelope. Two circuits were to be built across The Narrows to operate at 110 kv., with grounded neutral, each circuit to be of sufficient capacity to carry 300 amperes under normal conditions and 600 amperes in the event that one circuit might be out of service and the entire load thrown on the other. The Narrows being a navigable body of water, the War Department required that a conductor clearance of 200 ft. above high tide be maintained. The Washington State laws governing electrical construction specify that transmission lines shall be designed to withstand a wind load of 8 lb. per sq. ft. on the projected diameter of the conductor when incased with ½ in. of ice, at a temperature of zero deg. fahr., and under these conditions shall have a factor of safety on the ultimate strength of the conductor of not less than two.

The inherent objection to a steel cable as a conductor arises because of the high electrical losses and the resultant heating in the cable which seriously impairs its strength if the temperature of the conductor is permitted to exceed the temperature at which the annealing of high strength steel begins. This temperature is quite generally agreed upon by steel cable manufacturers as being approximately 400 deg. fahr., if that temperature is maintained for long periods of time.

Concentric cable has the advantage of having more cross sectional area of material for a given diameter than any other form of stranding, thus presenting less diameter to the wind and offering less surface for the formation of ice for a given strength of cable. The electrical losses of such a cable may be minimized by reducing the size of the individual strands to the least practical diameter and reversing the direction of the spiraling of the successive layers.

Tests to determine the losses and heating were conducted on two samples of cable, each one inch in diameter and composed of 37 strands of galvanized steel having an ultimate strength of 195,000 lb. per sq. in., as a cable, after the galvanizing and stranding operations. One sample had all strands spiraled in the same direction, and the other had the successive layers spiraled in the opposite direction. These tests indicated that at 300 amperes, the normal full load of each

1. Both of the Cushman Power Project, Tocoma, Wash.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash. Sept. 15-19, 1925.

transmission line, the electrical losses in the cable having the reverse lay were only 60 per cent of the losses of the uniformly spiraled cable. Thermometer readings of the surface temperature indicated that even with the reverse lay cable to carry 600 amperes of current in one transmission circuit, using steel cable of the required strength, a diameter of at least 1¼ in. would be required to insure that the annealing temperature would not be dangerously exceeded.

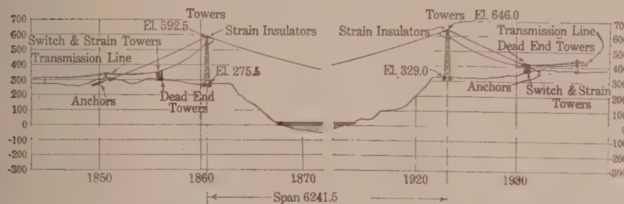


Fig. 1—General Diagram of Crossing

A 1¼in., 35-strand, specially constructed, concentric, reverse lay, steel cable having an ultimate strength of 180,000 lb. after galvanizing and stranding, was chosen as offering the greatest economy in the first cost of the complete aerial crossing and its subsequent operation.

Circuit Arrangement

The general design of the crossing is shown in Figs. 1 and 2. The conductors are arranged in a horizontal plane 30 ft. between phases and 120 ft. between the two circuits. The four main towers are each 316 ft. 6 in. high from the tower footing to the point of cable support at the top of the tower and are of the simple prop type. The conductors proper terminate at a nest of 12 multiple strings of high-strength suspension insulators, each string consisting of 11 units, equalized by means of springs to insure the proper mechanical loading of the individual strings, and the entire assembly attached to the supporting cables which pass over large sheaves on the top of the main towers and thence down and back approximately 900 ft. to anchors imbedded in the earth.

Jumper cables of copper attach to the steel conductors of the long span on the water side of the main towers and are carried through and around the latter back to switching towers near the main cable anchors. Disconnecting switches are provided here to isolate either crossing circuit and to multiple the transmission lines through one crossing circuit, or if necessary any three of the six conductors crossing The Narrows may be selected for a circuit and tied in with both transmission lines.

General Structural Design

To reduce maintenance cost, and to attain the utmost dependability in service, simplicity of design was sought in all features.

Investigations were conducted over a period of several years and such information gathered as was available concerning similar installations, notably the crossings of the Pacific Gas & Electric Company and of the Great Western Power Company over Carquinez Straits, the Knoxville Power Company's crossing over the Little Tennessee River, and the crossing of the Shawinigan Power Company over the St. Lawrence River. Considerable correspondence was carried on and some interviews were had with the engineers and officials of the companies mentioned.

In the design of towers, foundations and anchors it was possible to proceed along the lines of standard practise. Matters concerning the strength and other characteristics of cables,—fittings and insulators—are now also fairly well established. However, the question of the behavior of this equipment under service similar to that proposed, opens up a large field for discussion and research, probably the most troublesome consideration being the matter of vibration in long suspended cables.

It was desired to avoid, so far as practicable, all undesirable features affecting upkeep and continuity of service, as experienced in similar installations.

It was early decided that a messenger span with 1⅜ in. concentric strands, working at a factor of safety

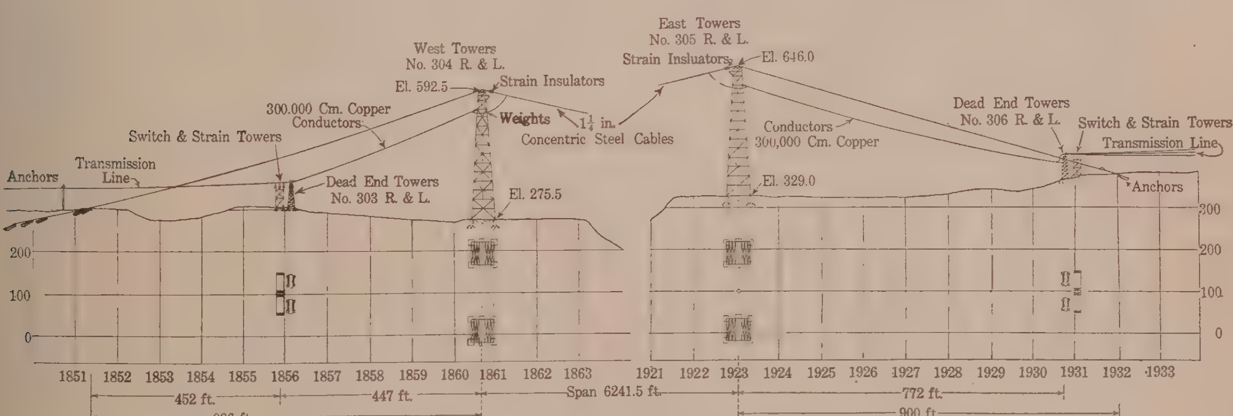


Fig. 2—Elevation and Plan of Crossing

of two and supporting separate conductors, would be the most desirable arrangement, the suspension insulators to be placed at irregular intervals to damp vibration. Further study, however, led to the final adoption of $1\frac{1}{4}$ in., 35-wire concentric steel strands, acting as self supporting conductors, using a factor of safety of three based upon the ultimate strength of the strand, and

The costs of cables, and fittings, towers and anchors were interdependent and must be computed as a whole for each design.

It was found that, as size of cables and consequently tower heights and anchorages were varied within practicable limits, the total cost of the complete crossing remained comparatively fixed.

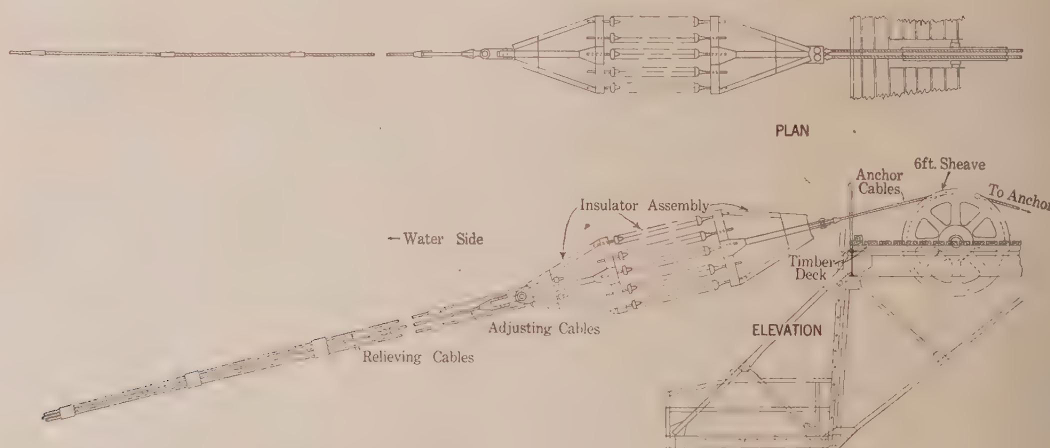


FIG. 3—SHOWING ASSEMBLING OF INSULATORS

supplying at the supports and anchors, devices in the way of fittings and relieving cables which would minimize the stresses and effects set up by vibration.

The combination of devices adopted are believed to be novel, but some of these features have been suggested by similar installations.

It has been the aim throughout, wherever indeterminate shocks and variations of stress are to be expected, to provide such ample factors of safety as to remove all possibility of failure from these sources.

It was therefore decided to base the design upon $1\frac{1}{4}$ in. cable, as being the smallest size that would satisfy electrical requirements.

As to possible necessity for replacement, it is interesting to note that some of the cables of the Pacific Gas and Electric Company's span, under similar conditions, have been in continuous service for 24 years, with an unknown length of useful life still remaining. Examination of one of these cables showed the outside wires to be only slightly deteriorated and the interior wires to be in perfect condition, with galvanizing unimpaired.

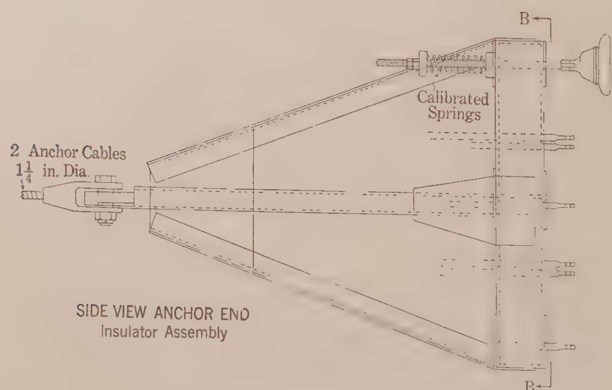


FIG. 4

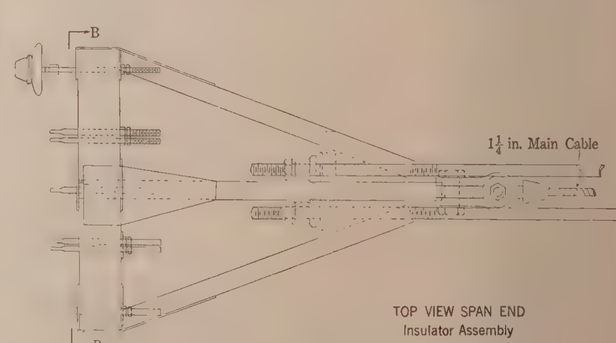


FIG. 5

ECONOMICAL CONSIDERATIONS AFFECTING SAG AND TOWER HEIGHTS

The factor of safety to be provided in the cables having been decided upon, comparative estimates were prepared, based upon various cable sizes, and the corresponding sags, tower heights, anchors, etc.

CABLES AND FITTINGS

The cables for this crossing will be $1\frac{1}{4}$-in., 35-wire, galvanized strand, consisting of acid, open hearth, plough-steel wire. The net area of steel in the strand is 0.93 sq. in., and it will weigh approximately 3.25 lb. per linear foot.

The guaranteed ultimate breaking strength of this strand is to be 180,000 lb., and tests already carried out show strengths well over this figure. Each coil of galvanized wire going into the make-up of the cables is being tested, the breaking strength running between 210,000 lb. and 220,000 lb. per sq. in.

Under maximum loading of ice and wind, the working stress in the cables was taken at 60,000 lb., affording a factor of safety of three, and the corresponding sag for determining clearance at 32 deg. fahr., when laden with ice will be approximately 397 ft., with a stress of 56,500 lb. Stringing stress at 70 deg. fahr. would be about 43,000 lb.

The main cable, considering one cable only, is attached by an open socket and clevis to the front of the insulator assembly, as shown in Fig. 3. One 90 ft. and one 70 ft. relieving cable will extend out from insulator assembly along the main cable. The outer ends of these relieving cables are to be securely served to the

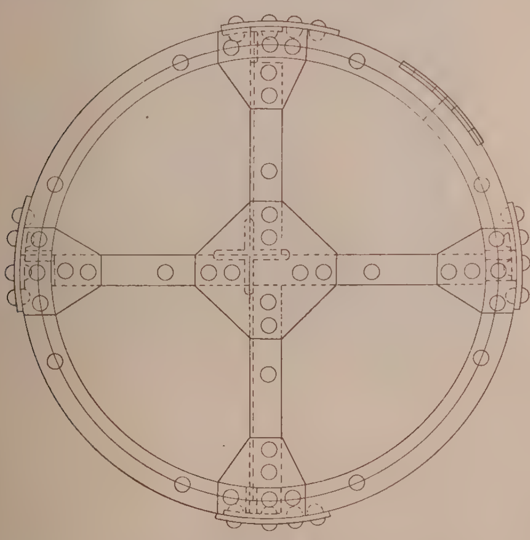


Fig. 6—Cross Section of Insulators

main cable and also attached thereto by a series of evenly spaced U-bolt clamps of cast steel. While these clamps are being attached, the relieving cables will be stressed in successive increments by means of the long threaded eye-bolts attached to front of the insulator assembly, in order to put the same amount of stress on each clamp.

From the back of the insulator assembly, two anchor cables will pass over the sheaves and attach separately to evener at front of anchorage by means of adjustable bridge sockets.

The purpose of the relieving cables, with their load of clamps, is to reduce stress in the main cable and damp vibrations, while the two anchor cables give double strength where passing over the sheaves and facilitate replacements or take-up.

All cables are identical, except that the main cables are reverse lay, while relieving and anchor cables are ordinary lay.

Insulator Assemblies

The question of insulation appears to be adequately solved by the design of insulator assembly adopted,

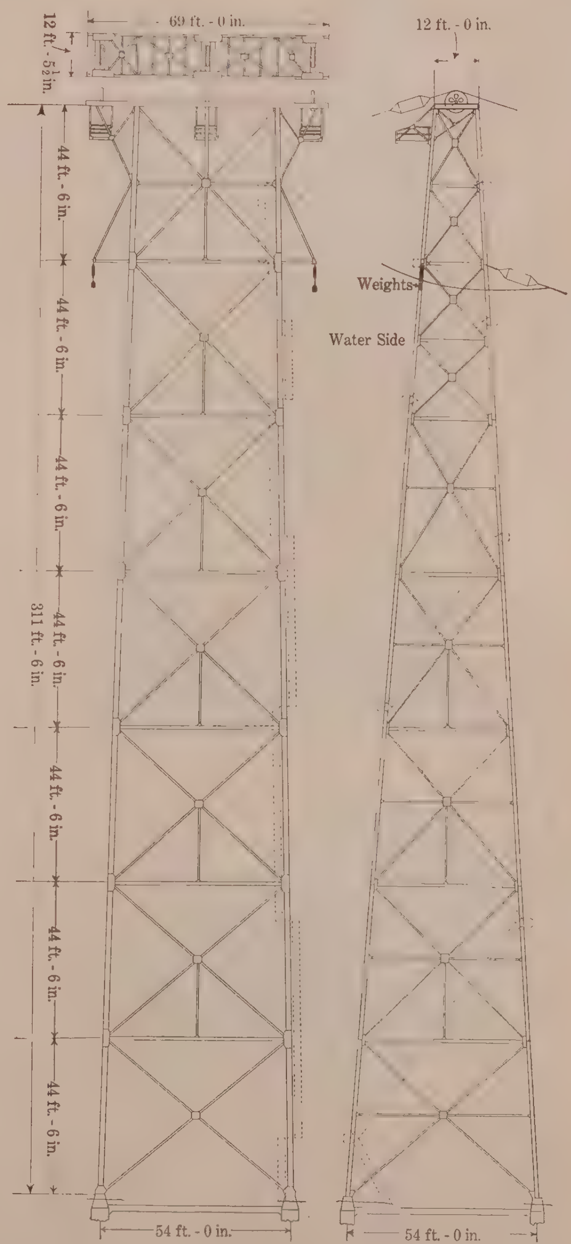


Fig. 7—Side Elevation of Tower

see Figs. 3 to 6. This consists of two rigid steel frames or yokes, conical in general form, and constructed of light channels, angles and bent plates.

Between these yokes are placed twelve strings of high

strength suspension insulators, eleven units to the string. The minimum ultimate strength of these units is 18,000 lb. while the working stress will be 5000 lb., which closely parallels the conditions of service found to be satisfactory on the span of the Great Western Power Company.

The two yokes are identical except as to the arrangement for cable attachment.

Calibrated springs are provided at the rear end of each string to equalize stress and assist in eliminating shock.

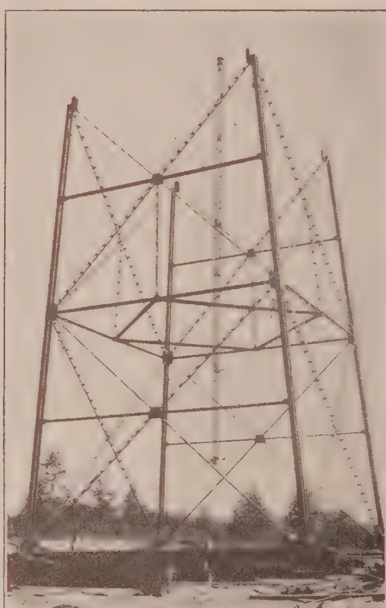


Fig. 8—Erecting Tower with Floating Gin Pole

With this rigid form of yoke, the breakage of any string would only slightly unbalance the loads carried by the other strings and a broken unit may be replaced and the string brought up to the proper working tension by means of the eye-bolts and springs.

During erection the insulators may be replaced by steel rods.

Towers

The towers are rectangular in form, 54 ft. square at the base, in which least number of members and ease of erection were considered together with economy of material, see Fig. 7.

Although the foundations on one side of the crossing are 53½ ft. higher than on the other side, it was decided to make the four towers of the same height, and identical in all respects.

The towers are 313 ft. from top of concrete to top of deck girders, consisting of seven 44 ft. 6 in. panels plus the depth of the 18 in. deck girders. The sheaves and bearings add another 3 ft. 6 in., making the total height from top of foundations to point of cable support 316 ft. 6 in.

The maximum computed reaction at base of the columns is 310,000 lb. and the greatest uplift 89,000 lb., the greatest stress in any of the diagonals being 33,500 lb.

Due to the importance of the structure as a vital link in the transmission line, and due also to legal regulations, the following conservative working stresses were adopted:

	Lb. per sq. in.
Tension:	
Rolled Steel	18,000
Bolts (net area)	12,000
Bearing:	
Pins, Shop and Field Rivets	20,000
Shear:	
Web Plates	10,000
Pins, Shop and Field Rivets	10,000
Extreme Fibre Stress:	
Rolled Steel Shapes	16,000
Rolled Steel Pins	20,000

Columns or Struts Axially Loaded:
Working stress not to exceed 18,000-70l/r, and not to exceed 14,000 lb. per sq. in.

Slenderness Ratio l/r:
Not to exceed 120, except for bracing and members resisting wind only, where l/r not to exceed 150.

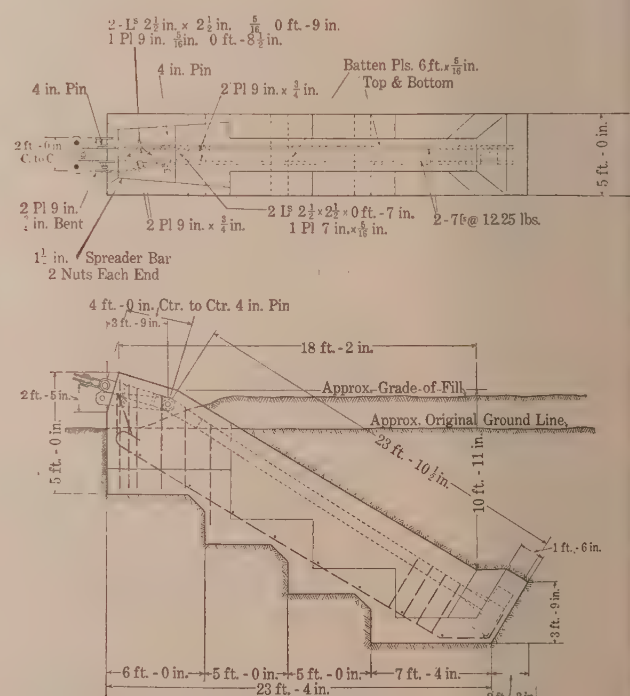


Fig. 9—Plan and Elevation of Anchor

A wind pressure of 20 lb. per sq. ft. was assumed on the projected area of all steel members.

The details of the towers are notable for the entire absence of latticing.

For economy of material, accessibility for painting

and other considerations, the familiar built-up type of column was selected, consisting of an I-beam and two channels, the largest section being one 12-in. I of 31.8 lb. and two 12-in. [s of 30 lb. at the base of the tower; and one 9-in. I of 21.8 lb. and two 8-in. [s of 13.75 lb. for the upper sections. The lower diagonals are two [s 3½ in. by 2½ by 5/16 in., battened. The minimum thickness of metal used is 5/16 in., with possibly a few minor exceptions.

For a slight additional cost above that of a simple

Fig. 10—Completed Anchor—Back View

ladder, a light stairway with convenient landings is provided on each tower.

Platforms extending out under the strain insulator assemblies facilitate inspection. These platforms are pin-connected to the main structure and can be swung down out of the way if desired at any time. The hand rails surrounding the platforms are also easily folded flat on the deck.

The total weight of each tower is 260,000 lb.

Tower Footings

The footings consist of simple concrete stepped footings, 12 ft. square, surmounted by 5 ft. square shafts. Four 2⅜ in. anchor bolts are embedded therein, extending to a steel plate 12 inches above the bottom of the footings. The footings are carried to a minimum depth of 9 ft. 6 in. below finished grade of the sites and are connected just below grade by 18-in. by 24-in. reinforced, concrete struts.

Anchorages

From several preliminary designs, a somewhat novel type of cable anchor affording a large factor of safety and eliminating any apprehension from this feature of the structure was decided upon. Fig. 9 to 11. The lower faces of the anchors are stepped and the entire excavation is in firm compacted gravel, which gives them a power of resistance which is impossible to calculate with accuracy, and provides a large margin of strength for any possible future requirements.

The structural steel members to which the anchor cables are attached are carried to the extreme back end of the anchors.

The steel eveners are so designed as to permit one anchor cable to be completed slackened off and removed without cramping the terminal socket of the other cable.

Extra eye-bars are provided for haul-back purposes.

Sheaves

Built up structural steel sheaves 6 ft. in diameter, with cast steel rims, were originally designed for the support of the cables, but one piece cast steel sheaves have been since manufactured for this purpose, the castings being exceptionally perfect and free from flaws.

The shafts are forged steel 7 in. in diameter, turned down to 5 in.—where they rest in bronze bushed bearings.

Each sheave weighs approximately 5000 lb. Calculations indicate that variations in loading may cause these sheaves to rotate approximately 13 in.

Construction and Erection

The foundations and cable anchors were constructed during the winter of 1924-25 at a cost of $33,000, and the contract for the fabrication and erection of the main towers together with the switching towers and stringing of cables was awarded Feb. 16, 1925, to the Star Iron and Steel Company of Tacoma, at a contract price of

Fig. 11—Group of Anchors at East End of Cables

$149,000, the towers to be completed by Sept. 19, 1925 and the cables to be strung by Oct. 19.

The contract for furnishing cables, fittings and insulator assemblies was awarded Feb. 13, 1925, to the John A. Roebling's Sons Company, at a contract price of $37,600, delivery to be made Aug. 25; making the complete cost of the crossing $219,600.00.

Erection was begun on the switching towers May 21, and the first steel column of the main towers was set June 6th, and the erection is progressing rapidly.

A 90 ft. basket or floating gin pole is being used, suspended in the center of the tower by four sets of falls attached to the columns at the panel points, the top being controlled by four lines operated by hand winches attached to the 18 in. by 24 in. concrete struts between footings.

Upon the completion of each panel the pole is raised or "jumped" 44 ft. for erecting the next panel. This method of erection has been used on many of the radio towers constructed in recent years.

COST OF DEVELOPMENT

The cost of the development of the first 50,000 h. p. of the Cushman Power Project will be approximately $5,000,000.00 and is being carried on under the general supervision of J. L. Stannard, Chief Engineer.

The authors wish to express appreciation of the courtesies extended by J. P. Jollyman and L. J. Corbett of the Pacific Gas & Electric Co., J. A. Koontz of the Great Western Power Co., Theodore Varney of the Aluminum Co. of America, and S. Svenningson of the Shawinigan Power Co. Limited. C. C. Sunderland of the J. A. Roebling's Sons Co., also rendered valuable service when the matter of steel cables was under consideration.

Recent Advances in the Communication Art

By Committee on Communication[1]

THE name of this committee has been changed from "Telegraphy and Telephony Committee" to "Committee on Communication." This was done in accordance with a recommendation of the special committee who reviewed the technical activities of the Institute. The Communication Committee feels that this is a desirable change in name.

In this report, under appropriate headings, are briefly summarized the advances which have been made, or which have come into prominence in the communication art during the past year. Thirteen papers have been presented to the Institute under the auspices of this Committee. These papers are in general a record of advances in the art, and are mentioned under the appropriate headings in the report.

Telegraphy. The development of long telephone cables of 19 and 16-gage, capable of operating for distances of 1000 miles and more, has led to the development of telegraph systems suitable for operating through these cables. These telegraph systems, developed by the engineers of the Bell Telephone System, were described in three papers presented at the Midwinter Convention. The titles of these papers were "Metallic Polar Duplex Telegraph System for Long Small-Gage Cables," "Voice Frequency Carrier Telegraph Systems for Cables" and "Polarized Telegraph Relays."

The first paper describes a type of telegraph circuit, designed to operate over cable telephone wires at frequencies below the telephone range, and without interfering with the telephone circuits using these same wires. In this system it was necessary to reduce the telegraph operating currents to values comparable with those used in the telephone circuits in order to prevent interference with the telephone circuits by the telegraph circuits. One form of interference which has thus been avoided is called the "flutter effect" and is caused by the telegraph currents affecting the magnetic characteristics of the loading coils in the telephone circuit, so as to cause a rapid fluctuation of received current. This telegraph system is on a balanced two-wire basis in order to diminish crossfire between telegraph currents and the effect of any currents induced in the cable.

The second paper describes a carrier type of telegraph system which makes use of a regular four-wire long distance cable circuit. No telephoning is carried on over the circuit when employed for the telegraph system, but the frequencies which are ordinarily involved in a telephone conversation are used to transmit ten telegraph messages in each direction. A separate frequency is employed for each message spaced in the frequency range from about 400 to 2000 cycles. No change is required in the telephone circuit except at its terminals.

These telegraph systems required the development of very sensitive and reliable relays which are described in the third paper noted.

Submarine Telegraphy. The Western Union Telegraph Company has put into service its new permalloy loaded submarine telegraph cable between New York and the Azores Islands. This type of cable, developed by the Western Electric Company, was described in last year's report. It represents the most radical change in the submarine cable art since its earliest days. The finished cable has fully met the expectations stated in the last report, and has so well established the success of this type of cable that the Western Union has ordered a second loaded cable to be laid between New

1. Annual Report of Committee on Communication.

O. B. Blackwell, Chairman

F. L. Baer,	Sergius P. Grace,	F. A. Raymond,
H. P. Charlesworth,	P. J. Howe,	Chester W. Rice,
L. W. Chubb,	F. H. Kroger,	J. K. Roosevelt,
C. E. Davies,	N. M. Lash,	Edgar Russel,
H. W. Drake,	Ray H. Manson,	H. A. Shepard,
R. D. Evans,	G. W. McRae,	E. B. Tuttle,
L. F. Fuller,	R. D. Parker,	F. A. Wolff,
D. H. Gage,	H. S. Phelps,	C. A. Wright,

Presented at the A. I. E. E. Annual Convention, Saratoga Springs, N. Y., June 24, 1925.

York and Penzance, England, by way of Newfoundland. A paper describing the development of this type of cable will be presented at this convention.

During the year 1924, the Western Union Telegraph Company developed a printing telegraph system for use on ocean cables. It has been in commercial operation on a transatlantic cable circuit between London and New York. In this system, signals sent from a transmitter at London are translated and printed in Roman characters at New York without manual handling at any of the intermediate repeater stations.

The initial circuit consists of an underground pair between London and Penzance, England, 312 miles; ocean cable, Penzance to Valentia, Ireland, 307 nautical miles; ocean cable, Valentia to Heart's Content, Newfoundland, 1874 nautical miles; Heart's Content to North Sydney, Nova Scotia, 335 nautical miles; overhead land-line North Sydney to New York, 1110 miles; or a total of approximately 3900 miles. Regenerative automatic repeaters which regenerate the signaling impulses as to strength, shape and time are used at Penzance, Valentia, Heart's Content and North Sydney and universal duplex repeaters are used at St. John (New Brunswick) and Boston.

The code used is of the five-unit type, the same as is used in the Western Union Multiplex system. Tape printers are used at New York for translating the signals. The printer prints in Roman characters upon a gummed strip of paper ⅜ in. wide and this strip is gummed to regular cable message receiving forms for delivery.

Telephone Signaling. The use of 16 to 20 cycles alternating current for telephone signaling was developed in the very early days of the art, and is still employed, not only for ringing subscribers, but also for signaling on many toll lines.

The introduction of composite telegraph circuits brought about the introduction of 135 cycles for signaling, in order that the signaling should be at a frequency which was not used in the telegraph signals. Considerable improvements have been made recently in 135-cycle signaling, and it is being employed on very long circuits requiring many repeaters.

More recently voice-frequency signaling systems have been developed particularly for operation over very long repeater circuits. By thus using a frequency in the voice range, any circuit over which speech can be effectively transmitted also effectively transmits signaling currents of this frequency. Since the signaling is carried out at intervals when there is no talking on the circuits, there is no interference with the speech currents. It is evidently necessary, however, that some means be provided to prevent the speech currents from operating the relays employed with this system. This is taken care of by interrupting the signaling current approximately 20 times per second, thus producing a form of current which is not produced by the voice. A relay system arranged to operate with such current will not be operated, therefore, by any voice current.

An improved signaling system for taking care of the signaling and control arrangements necessary for handling calls over the wires of a toll circuit group, is being applied in the toll plant. By the use of this system the signaling and control arrangements for as many as 30 circuits are handled over a single pair of wires, thus freeing a large number of channels for telegraph purposes.

Machine Switching. During the past year, continued progress has been made in perfecting improvements in machine-switching equipments. These improvements are the result of intensive development work and have been made with a view of facilitating manufacture, installation and operation of central offices and private branch exchanges of this type. Progress has also been made in the development of new maintenance methods and tools, and in stabilizing the maintenance methods employed. This is of importance due to the large amount of apparatus involved in automatic operation, and the dependence that must be placed on it when connections are completed by machine switching.

The theory of probability plays a very important part in the design of switching systems, and in the determination of the amount of facilities required to meet various traffic conditions. A paper on "The Theory of Probability and Some Applications to Engineering Problems" was presented at the Midwinter Convention. Only a very few papers on this important subject have ever been presented to the Institute.

On December 31, 1924, there were 993,000 stations operating on a machine switching basis in the Bell System as compared with 567,800 switching stations at the end of 1923. In New York City there were 185,300 machine switching stations in service on December 31, 1924, operated from a total of 21 central offices.

The application of machine switching to the toll plant is being studied with a view to determining where it can be employed to advantage. An installation is being made of this system on a commercial basis and if found successful it will be extended.

Coincident with the development work on machine-switching equipments, considerable progress has been made in manual switching, particularly with respect to trunking methods. These improvements have been effected largely by the increased use of automatic methods in connection with the manual handling of calls and have resulted in reducing the manual labor necessary in completing telephone connections.

Telephone Distributing Frame Wire. Improvements in means for flame-proofing wires, developed in the Bell System's Laboratories, have resulted in the production of rubber-insulated wire showing resistance to burning fully equivalent to that obtained in flame-

proofed enamel and textile insulated wires. This wire is particularly adapted for use in the distributing frames of central offices. The rubber-insulated wire, so flame-proofed, possesses advantages in electrical characteristics and cost over alternative forms.

Telephone Transmission. An extensive investigation has been carried out by the Bell Telephone engineers with regard to the characteristics of speech and of hearing. A considerable number of papers have been published on this work. This analysis of the characteristics of speech has made it possible to determine accurately the effect of different frequency ranges on the intelligibility, loudness and naturalness of the spoken word. It is interesting to note that a large proportion of the energy of the voice is in the low range of frequencies of a few hundred cycles, while the higher frequencies up to several thousand cycles are of importance in providing clear articulation. As a by-product of these researches, important scientific results are being obtained regarding the nature of hearing, and methods of aiding the deaf and the dumb.

A paper entitled "Telephone Transmission Maintenance Practises," read at the Pacific Coast Convention, described the practise employed by the telephone companies in this country to guarantee their circuits maintaining a condition for giving the best transmission results. These practises are of the greatest importance in maintaining both toll and local circuits.

A paper read at the San Francisco Convention, entitled "Guided and Radiated Energy in Wire Transmission," gives a good discussion of transmission over wire circuits, and the conditions under which part of the energy is radiated from such circuits. This is a matter of fundamental technical importance since so much of our electrical art depends on the fact that electromagnetic waves may be guided by conducting wires.

Telephone Circuits have become so long, both geographically and electrically that echoes may be set up in them. The effects produced are very similar to those with sound waves. Whenever a voice wave meets an electrical irregularity in a circuit, some part of the wave is reflected. If the time required for the speech waves to travel to the irregularity and for the reflected waves to return to the speaker or listener is sufficiently great, the effect becomes an echo. A discussion of such echo effects and arrangements devised for avoiding them where they become of importance was described in a paper before the St. Louis Convention entitled "Echo Suppressors for Long Telephone Circuits." It is in telephone circuits of such length as to require a number of repeaters, particularly in long cable circuits that the effects may become sufficiently serious to justify the echo suppressors which are described. With these suppressors, the speech currents operate relays which block the echoes without disturbing the main transmission.

Outside Plant Practises. Tests of full size poles of the various timbers used in telephone work have recently been made by the Bell System engineers, in order to redetermine their moduli of rupture. These tests are probably the most comprehensive that have ever been made on full size specimens, and it is hoped that a paper can be obtained during the coming year describing the tests and giving the results obtained.

Drop wire having the two insulated conductors placed parallel under a common braid has been standardized for use in the Bell System. This is the type of wire used generally for connecting subscribers' stations with the nearest cable terminals. The new construction, in place of the twisted pair construction formerly employed, results in reduced accumulation of ice loads, better resistance to abrasion, and in simplified insulating supports. It costs less because of reduction in material required and simplification of the manufacturing operation. Extensive trials have shown that the long twists which occur in the removal of the wire from the coils, in view of the conditions under which it is used, are sufficient to prevent cross talk between adjacent circuits.

Radio. International radio telegraph circuits have continued to grow during the year 1924. The Radio Corporation of America has inaugurated a direct service between the United States and Sweden; and between the United States and Argentine—this being the first direct radio link between New York and South America. This Company has also established a station at Belfast, Maine, for reception of messages from Europe. The signals received are automatically relayed by radio to the Riverhead receiving station. Because of reduced static, and also the somewhat shorter distance, the signals received at Maine and thus relayed to Riverhead are generally considerably better than those received directly at Riverhead.

Considerable progress has been made during the year in the substitution in the marine field of tube transmitters generating sustained oscillations for spark transmitters. This results in increased range of communication and decreased interference, both in the marine field itself, and to broadcast listeners. The Radio Corporation has completed its program for installing tube transmitters in all of its shore stations, and has inaugurated a program for converting the ship spark transmitters in which it is interested into tube transmitters.

Marked interest is being taken by shipping companies in the use of radio direction finders aboard ships. With the increased number of new ship installations, the Lighthouse Division of the Bureau of Commerce and Labor are increasing the number of radio beacons which will be equipped with tube transmitters. Ship installations of this kind are not only of importance in determining the position of a ship, but also enable it to determine quickly the direction of a ship in distress.

An interesting development in ship-to-ship and ship-to-shore telephony are the radio sets built by the

Western Electric Company for the United States Coast Guard. These sets were designed to give voice transmission up to 50 miles, and telegraph transmission up to 100 miles. They use one-wave length only, which will lie between 100 and 200 meters. The transmitter is of the coupled oscillator type, of 50 watts output, and the receiver is of the double detection (so-called super-heterodyne) type.

A brief statement was given in last year's report of the developments in the use of short waves of 100 meters and less, and the surprising results which had been obtained with them under some conditions. A large amount of further information has been obtained as to the characteristics of these waves, and attempts have been made to explain their action from the theoretical standpoint by Larmor (*Phil. Mag.* December 1924) and by Nichols and Schelling (*Bell System Technical Journal*), April 1925). While much more remains to be done before it will be possible to predict definitely the action of such waves, they are already being put into important practical use for telegraph purposes. Four of the long transatlantic circuits are now being supplemented by short-wave systems. These systems are still largely experimental, but it is understood they give promise of having considerable value. It has not yet developed, however, whether these short waves will displace the present use of long waves, or will rather enlarge the possibilities of radio.

The interest in these short waves led to a conference in England during July last, attended by representatives of the large radio telegraph companies in Europe and America. This conference discussed ways and means of intensively studying the short wave field. The use of short waves involves interesting and important possibilities of using directive systems at both the transmitting and receiving stations.

Under the auspices of the American Engineering Standards Committee, a Sectional Committee on Radio has been organized for the purpose of formulating standards in the radio field, particularly with respect to nomenclature and methods of rating and testing apparatus. The sponsor bodies are the American Institute of Electrical Engineers and the Institute of Radio Engineers.

Last year's report mentioned the fact that weekly tests of telephone transmission from America to Europe were being carried out, and that a committee appointed by the British Post Office had recommended the installation of a 200-kw. telephone transmitter at its new Rugby station for transmission to America. These weekly tests have been continued throughout the past year and the British Post Office is proceeding with the installation of the transmitter as noted.

The production in considerable quantity of high-frequency alternating currents for radio transmission involves some very important technical problems. A paper on "Frequency Multiplication," read at the St. Louis Convention, discusses one of the means of producing such high frequency currents.

Radio Broadcasting. Radio telephone broadcasting continues with unabated public interest. From the transmitting standpoint, there has been a steady increase in the number of better grade broadcasting stations. The problem of providing a sufficient number of frequency bands in which to accommodate them has become a serious one to the authorities of the Department of Commerce, no satisfactory solution having as yet been found. This matter, as well as other aspects of the broadcasting situation, was the subject of a National Radio Conference in October last—the third to have been called by Secretary Hoover.

The developments which have been made in the art of connecting together a considerable number of broadcasting stations by long distance wire telephone circuits is strikingly indicated by the arrangements which are now made for broadcasting national events. For example, a speech by President Coolidge on November 3, was broadcast simultaneously by 28 radio broadcasting stations scattered over the entire country from the eastern to the western seaboard.

Considerable development has been made in receiving sets. Regenerative equipment in which self oscillation is prevented only by proper manipulation by the operator, is coming into disfavor and being supplanted by sets employing multi-stage radio frequency amplification, or sets of the so-called "super-heterodyne" type. Sets of these types do not interfere with each other and give good speech and music quality together with high selectivity.

The loud speakers associated with radio sets have in general presented more difficult problems in attaining high quality reproduction than have the sets themselves. Last year's report mentioned two papers which had been presented during that year to the Institute on this matter. With one of these papers was demonstrated the so-called cone-type of loud speaker developed by the Bell System engineers. This loud speaker has since been put on the market. It properly reproduces the low frequencies whose lack has been perhaps the most unfortunate characteristic of broadcast reception from a musical standpoint. At the same time it permits a better reproduction of the higher frequencies.

A paper entitled "A New Hornless Type of Loud Speaker," read at the St. Louis Convention, describes the development work on loud speakers carried out by the General Electric engineers and in particular a form of hornless loud speaker which they have developed. It is expected that this development will form the basis of a high-grade loud speaker to be put on the market.

It is very important with high-grade loud speakers that the voice frequency amplifiers associated with them, as well as the radio set, be free from distortion.

A paper entitled "The Design of Distortionless Power Amplifiers," read at the Midwinter Convention, discusses the problems which arise in the design of such amplifiers and the means for overcoming them.

Inductive Relations of Power and Communication Circuits. In response to a demand for a body representative of all wire-using utilities to carefully consider the technical problems of inductive coordination, the American Committee on Inductive Coordination was organized. This committee is made up of representatives of the American Railway Association, the American Electric Railway Association, the National Electric Light Association, the Western Union Telegraph Company, the Postal Telegraph-Cable Company and the Bell System. This committee has perfected an organization, agreed upon a program, appointed subcommittees and has issued its first report.

The Joint General Committee of the N. E. L. A. and the Bell System has continued its cooperative work throughout the year. The comprehensive investigation by the Development and Research Subcommittee has been divided into eleven projects, and each project put in charge of a small Project Committee. The program includes both theoretical and experimental work in the laboratory and in the field. Subjects under investigation include; coupling coefficients between power and telephone circuits; effectiveness of coordinated transpositions; effects of unbalances in telephone circuits and means for locating and clearing them; the cumulative effects of successive exposures; protection of telephone circuits from acoustic and electric shocks; residual voltages and currents in power circuits and methods for their control, including effects of isolating and grounding the neutral by different means; noise in telephone circuits, its effects, frequency composition, methods of measurement, and survey of its magnitude and distribution; wave shapes of voltage and current in power circuits and the development of means for improvement and rating; inductive effects under joint use of poles or other conditions of close exposure; the effects of changes in the power level and sensitivity of telephone circuits; selective devices for suppressing undesirable frequencies in either or both systems; characteristics of telephone receivers and transmitters; special devices for application to either or both systems; and interference with carrier frequency channels. It will require a period of several years to complete these investigations, but it is planned that important results will be made generally available from time to time.

Fig. 1

The paper on "Telephone Circuit Unbalances—Determination of Magnitude and Location," read at the Pacific Coast Convention, covers a matter of large importance in considerations of inductive interference.

Electrical Protection. The National Fire Protection Association, through its Committee on Signaling

Systems, has undertaken a complete revision of the Regulations for Municipal Fire Alarm Systems, and for Protective Signaling Systems. The Electrical Committee of the Association is engaged in a triennial revision of the National Electric Code, including the Regulation for Wiring of Signaling Systems and Radio.

Communication in Railroad Operation. Communication plays a very important part in railway work. A paper on "Communication in Railroad Operation" read at the St. Louis Convention discusses this matter from the railroad standpoint.

and New Haven, Connecticut. Telegraph signals, set by observers at five points at the instants when the eclipse became total to them, were recorded on a chronograph in conjunction with seconds beat by a very accurate electric clock.

Careful observations were made by a number of the communication companies, and by others interested in radio, as to the effect of the eclipse on radio transmission. Definite correlation between the passage of the shadow of the eclipse and radio transmission appears to have been well established in some cases.

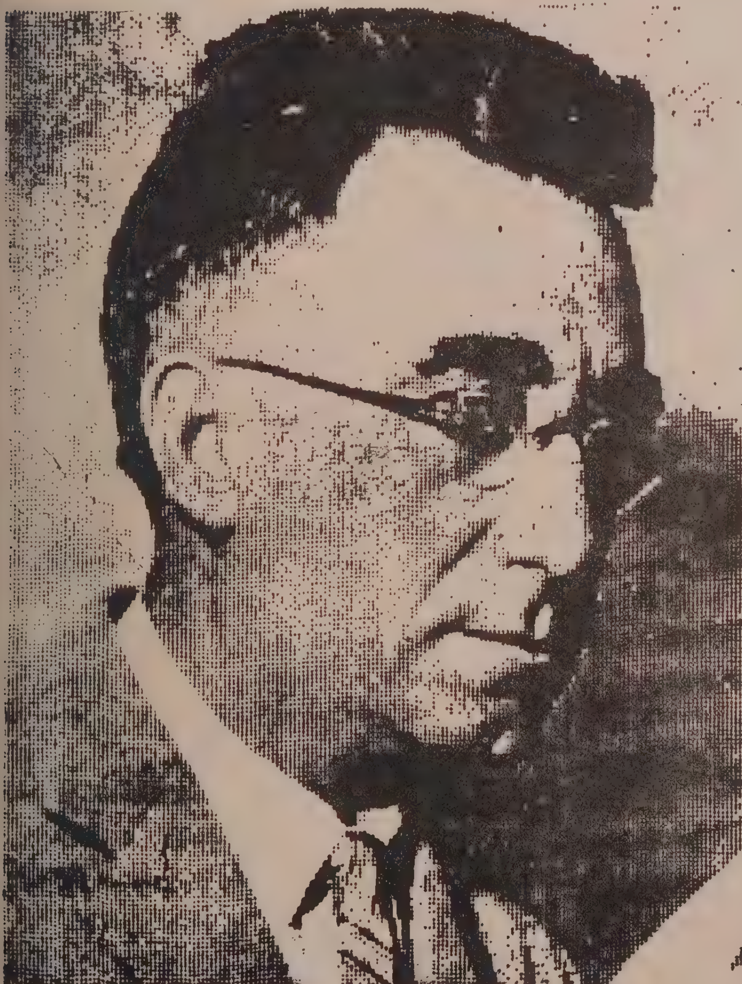


Fig. 2

Fig. 3

Solar Eclipse. The eclipse of the sun in January was of special interest to communication engineers, in that communication facilities played a very important part in the scientific observations which were made, because of the effect of the eclipse on radio transmission.

At the request of the American Astronomical Society, the telephone companies arranged circuits connecting observing parties at Buffalo, Ithaca, Poughkeepsie, East Hampton and New York, N. Y., and Middletown

Electrical Transmission of Pictures. There has been a large amount of activity during the year in the electrical transmission of pictures.

The report for last year gave a brief description of a system developed by the Bell Telephone System engineers for transmitting pictures over telephone lines. Further development has so far perfected this system that the transmitted pictures present an appearance differing very little from that of the original photo-

graph. Fig. 1 is a reproduction of a picture so transmitted, and shows the great amount of detail obtained. The picture was transmitted directly from an ordinary positive film, and about seven minutes was taken in transmission. Pictures of the inauguration of President Coolidge on March 4 were transmitted from Washington, D. C. and received simultaneously at New York, Chicago and San Francisco, and were published in the afternoon editions of the newspapers of that same day. Commercial picture service with this system has been inaugurated between the three cities of New York, Chicago and San Francisco. The system is described in a paper appearing in the *Bell Systems Technical Journal* for April, 1925.

The lines of the Western Union Telegraph Company have been used commercially by a number of newspapers for the transmission of photographs by a method devised by M. Ferree and J. Wissmar. In this system, the elements constituting the picture are sent over the line wire and handled in exactly the same manner as the signal impulses used in the transmission of ordinary telegraph messages. At the sending end a stylus moves in spirals over a specially prepared cylindrical plate. Current impulses flow through an electric circuit, of which the stylus and plate form a portion, whenever the stylus rests upon a light portion of the plate and operate a telegraph pole changer. The current reversals caused by the pole changer operation are transmitted to the receiving station or stations through the line wires and such telegraph repeating apparatus as is necessary. At the receiving station a relay opens and closes an electric circuit, in which is included a stylus which travels spirally over a chemically prepared paper. By the action of these electrical impulses upon the treated paper, marks are made so that a picture is formed corresponding to that on the sending plate. The system described has been successfully used on a circuit lay-out arranged for duplex operation, and made up of about 5300 miles of line wire connecting to fifteen cities. Fig. 2 is a reproduction of a picture transmitted in this way. About one hour is required for transmission.

The Radio Corporation of America announced during the year transmission of pictures by radio from London to New York. Fig. 3 is a reproduction of a picture so transmitted. The method employed is, in brief, as follows: At the transmitting end, the picture to be sent is wrapped around a glass cylinder which is caused to revolve. As the drum revolves, a small concentrated electric light on the inside sends a beam through successive portions of the picture to a sensitive photoelectric cell. The current variations resulting are highly amplified, and are caused to charge a condenser in such a manner that the rate of charge is determined by the amount of light piercing the transmitting film. When a given voltage is reached on the condenser, the circuit trips and gives a pulse which works a relay to start a signal. When the amount of light increases beyond a certain point, the current not only is able to charge the condenser more quickly, but is so arranged that it will hold the relay for a greater length of time. This gives rise to a peculiar characteristic of widely separated dots for one end of the light scale, of close dots for the middle ground and long-drawn-out dashes for the other end of the photographic scale.

At the receiving end a paper sheet is fastened to a drum, which rotates in synchronism with the drum at the sending end. The radio signals, highly amplified, actuate a small fountain pen suspended just above the paper, which thus records on the paper the dots and dashes received by the radio, and thus forms the picture.

The rugged character of the dot and dash signals, such as has made possible long distance communication by radio telegraphy, carry these pictures through what would otherwise be considerable interference. The question of detail is a matter of the amount of time which can be devoted to the transmission. A portrait with the amount of detail shown can be handled in about twenty minutes.

A system devised by Edouard Belin, who has long been interested in picture transmission, has been tried out during the year between St. Louis and New York, and pictures so transmitted have been published in news-papers in both of these cities.

A number of other investigators have been carrying on experiments in picture transmission, among these being C. F. Jenkins, Austin G. Cooley, M. L. D. McFarlane and H. G. Bartholomew.

Education in Communication Engineering. There has been a steady growth of interest in communication courses in the teaching of electrical engineering, although the growth is perhaps less rapid than in the years immediately following the war. The tendency seems to be toward required rather than elective courses in electrical communication, probably due to the growing realization that such courses introduce the student to certain important fundamental conceptions and ideas which he would not get from his other courses. In August, 1924, an educational conference was held in New York City, in which a group of college professors met with officials of the Bell Telephone System. The discussion of various phases of electrical communication and the methods of teaching them were of much value to all those who attended the conference.

A considerable number of educational institutions are undertaking the broadcasting of courses of lectures, music, athletic events, and other matters of interest. This promises to become an important function of some of our universities.

Electric service is now starting on its 44th year. On September 4, 1882, the first metropolitan electric service company began operations. This was the plant built by Thomas A. Edison to supply electricity to the lower part of New York City.

Progress in Diverse Lines of Electrochemistry and Electrometallurgy

By Committee on Electrochemistry and Electrometallurgy*

TWO papers on electrochemical subjects have been presented at meetings of the Institute by members of this Committee. The first of these entitled "Electrometallurgical Applications" by J. L. McK. Yardley was presented at the Pacific Coast Convention in October 1924. This paper dealt with developments in the utilization of electrical power based upon fundamental principles of electrochemistry and the relation of the electrical engineer to the chemist and metallurgist. The second paper, by G. W. Vinal and G. N. Schramm, was entitled "Storage Battery Electrolytes." This was presented at the A. I. E. E. Midwinter Convention, February 1925. Measurements to determine the effect of a wide variety of impurities in the electrolyte were summarized and a proposed specification for using sulphuric acid in storage batteries presented for discussion.

The Committee has suggested to the Standards Committee the desirability of revising and extending the section on storage batteries in the Standards of the Institute. The section on the method of rating storage batteries is not entirely clear at the present time. Serious difficulties in the industry have recently arisen in the matter of rating the various sizes and kinds of storage batteries for use on automobiles and for radio purposes. However, the point to be considered, does not relate to the rating of particular types of batteries, but rather to the general principles for rating batteries and to clearer indication of how time and current ratings may be used. Revision of the definition of the word "charge" has been suggested as well as the possible addition of specifications for the purity of the solutions. The Standards Committee has acted favorably on these suggestions and the appointment of a working committee to include a wide range of those interested in the subject of storage batteries has been authorized. Mr. Vinal has been chosen chairman of this working committee.

A request for information on the physiological effects of electric currents, addressed to the Institute, has been referred to this Committee. In response to this inquiry a short bibliography on the subject has been prepared. This bibliography does not contain references to the therapeutical or strictly medical aspects of the subject nor to electrocardiographs. Since information on this subject does not seem to be readily available elsewhere and as it may be of interest to others, the bibliography is appended hereto.

The field of electrochemistry and electrometallurgy is so diverse, including as it does such contrasting subjects as potential measurements and electric furnaces; electro-plating and storage batteries; electrolytic rectifiers and the production of materials, that it is difficult to define its boundaries or to estimate the relative importance of achievements in the various lines of activity. Fortunately for the electrical engineer, interested in electrochemistry and electrometallurgy, there are available several up-to-date lists of titles of publications covering the entire field. These are found in both the monthly *Bulletin* of the American Electrochemical Society and the monthly issues of *Mining and Metallurgy*. These lists are generally more up-to-date than the abstract journals.

It is inevitable that no two summaries of the progress of the art in any particular field can be alike because of the limitations of individual knowledge and the trend of personal opinions. The following resumé, for which the Chairman of the Committee is largely responsible, aims to present very briefly significant points about the recent developments within the field of electrochemistry and electrometallurgy.

The rapid growth of the automobile industry and the still more recent development of radio have resulted in a great expansion of the storage-battery industry. The vexed question of how to rate storage batteries of certain types is still being discussed. Radio batteries are marketed as having a certain number of ampere-hours capacity, but no standard method of rating them has been adopted. One of the most notable, but less conspicuous achievements, has been the production of thin plate batteries for airplane service. Plates of 0.050 inch which would have been thought impossible not long ago are now in use. Contrasting the output of these batteries with the familiar automobile battery it is found that the capacity per pound has been increased from 50 to 75 per cent in spite of the handicap imposed in making them nonspillable. The life of the plates is from 50 to 100 cycles which together with the cost, limits their use to certain kinds of service. Our knowledge of the low temperature characteristics of these batteries has been extended.

Primary batteries especially dry cells have experienced notable developments chiefly as a result of the interest in radio. The production of dry cells which runs into the hundreds of millions per year has been accompanied by a general improvement in the quality. The establishment of Standards of Performance and the Specification of Tests have been instru-

*Annual Report of Committee on Electrochemistry and Electrometallurgy.

George W. Vinal, Chairman

A. M. Hamann,	W. A. Moore,	John B. Whitehead,
Carl Hering,	W. E. Moore,	C. D. Woodward,
E. T. Moore,	J. A. Seede,	J. L. McK. Yardley.

Presented at the A. I. E. E. Annual Convention, Saratoga Springs, N. Y., June 24, 1925.

mental in making this advance. The quality of well established brands has been improved, and by comparing records of performance of 1918 with 1920 and 1924, it is found that there are more manufacturers today whose cells comply with the government requirements than in 1920 when the requirements were not as severe. The American Engineering Standards Committee has asked the Bureau of Standards to act as sponsor for a representative sectional committee to undertake the standardization of dry cells and batteries. This committee is now being formed.

Further development of electric furnaces involves the important question of improving the refractories. A symposium on the subject of refractories was held by the American Electrochemical Society at its Spring Meeting in Philadelphia last year. During the slump after the War, there was some question as to whether electric melting of steel and brass would continue to increase at its former rate when conditions were again normal. The rate of increase now indicates that the "saturation" point is still far from being reached. Experiments have been reported that show a saving for the electric melting of brass over coke-fired pit furnaces. Improvements in automatic electrode control devices have been made. In the low-temperature furnace work and ovens for enameling, the adverse effect has been felt of certain recently developed auto finishes.

High frequency induction furnaces are finding increased use for laboratory and experimental purposes and also for small scale production. The larger sizes are now operated on high frequency generators which have replaced the oscillatory spark gap. The smaller units may be operated by electron tubes, obviating the risk of escaping mercury vapor. It is expected that applications to large scale uses will ultimately be made.

Ring-type horizontal induction furnaces of six tons capacity and 800 kw. are now in use.

From the standpoint of the electrical engineer the fertilizer industry represents an outlet for electrical energy that is dependent upon the demand for more concentrated fertilizers. Phosphoric acid is now made in the electric furnace. The development of processes for the fixation of nitrogen has indicated a trend toward decreased power requirements per unit of nitrogen. The arc process which was first developed involved a large power consumption. The cyanamid process, next in order of time, required only one fourth as much and more recently has come the synthetic ammonia process requiring only one sixteenth the power (without electrolytic hydrogen) of the arc process. But in this last case it is evident that the electrical power requirements will depend very largely upon how successfully the electrolytic production of hydrogen can compete with more strictly chemical methods. Electrolytic hydrogen is produced directly in a high state of purity which makes it well suited to the purpose. At the September meeting of the American Electrochemical Society to be held in Chattanooga there will be a symposium on the relation of the electrochemical industry to the production of fertilizers. This is to include papers on phosphoric acid, the production of hydrogen and the fixation of nitrogen.

Production of the lighter metals by electrolysis of fused salts has been stimulated by the demand for light-weight materials of construction and by the radio industry. Aluminum and magnesium are perhaps the most important. Developments in the technique of the electrolytic production of aluminum have been made during the past year. The ability to produce aluminum of very high purity will doubtless have an effect on its uses within the field of the electrical engineer. Experiments on beryllium and calcium have also been mentioned. A symposium on fused electrolytes was held at the Niagara Falls meeting of the Electrochemical Society, April 23-25, 1925.

Improvements in the electrolytic production of other metals have been recorded and electrolytic tin has been added to the list of commercial products.

Three methods for the production of electrolytic iron were described at the World Power Conference. During the discussion it was stated that electrolytic iron was an assured commercial possibility, but that it would not become a serious competitor of ordinary iron for some time to come. About 28 per cent of the caustic soda produced in this country is made by the electrolytic process. New outlets for chlorine products are being sought by the newly established Chlorine Institute, Inc. which has been created by a group of manufacturers.

Electrolytic rectifiers have become a subject of renewed interest as a result of the phenomenal growth of the radio industry. Improved forms of both the aluminum and tantalum rectifiers have recently appeared. These are designed for the charging of small batteries for radio receiving sets and the latter has also been found useful by railroads for charging signal batteries. Our knowledge of output and efficiency of these rectifiers in relation to the impressed voltage and the battery voltage has been clarified and the operating characteristics materially improved.

A promising method for the study of the instantaneous values of electrode potentials has been developed by the use of a resistance coupled vacuum-tube amplifier in combination with the oscillograph. By means of this amplifier it is possible to obtain sufficient power to operate the oscillograph without polarization of the cell, and on the other hand with current flowing through the cell it is possible to distinguish between the electrode potential and the $I R$ drop.

Scientific methods are being extended in the field of electroplating. Results of research and much practical experience are gradually being welded into a comprehensive theory of electrodeposition. The structure of electrodeposited metals has been studied and new methods for the regulation of plating baths and hydrogen-ion control have been introduced. Electrolytically deposited coverings for the prevention of corrosion have recently been the object of much study. The use of zinc for this purpose is increasing. Nickel does

not afford complete protection at the present time, but the technique of nickel plating is being improved. Experiments have also been made on chromium and cadium. Other preventives of corrosion include alternate layers of copper and nickel and the plating of alloy deposits such as brass, bronze and mercury-zinc.

Engineers are taking cognizance of the importance of the corrosion problem. The American Society of Testing Materials held a symposium on this subject in June 1924 and the American Electrochemical Society did likewise in October of the same year. More recently the American Chemical Society has taken the matter up and it is proposed to establish a corrosion institute. Whatever may be the outcome of conflicting opinions on the fundamental causes of corrosion, a theory for its prevention, involving both chemical and electrical agencies, will probably be ultimately agreed upon.

Use of the earth current meter during the past year has been gradually extended and there appears to be a general recognition that it affords a more accurate means for determining the rate of stray current corrosion than has been available heretofore. Its use is limited by the time and expense involved in making the excavations necessary for its use.

The recently published transactions of the first World Power Conference, London 1924 (Volume IV) contain papers on electrochemistry and electrometallurgy as follows:

The Austrian Electrochemical Industry, Paweck.

Small Waterpowers and Electrothermal and Electrochemical Loads, Bodex.

Nitrogen Fixation, Halvorsen.

A New Resistance Furnace with Reaction Zone, Holmgren.

Electrochemical Industry in Sweden, Palmaer.

Power in Electrochemical and Electrothermal Industries, Fitzgerald.

Electrical Engineering as a Leading Factor in the Development of Modern Steelworks, Geyer.

Electrolytic Iron, Hutchins.

Electrometallurgy in Italy, Giolitti.

Power in Electrometallurgy in the U. S., Mathewson.

The electrical engineer who is interested in electrochemistry as an outlet for power will find statistics of interest in several of these papers.

Appendix

PHYSIOLOGICAL EFFECTS OF ELECTRIC CURRENT

1. Physiological Effects in General

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Electromotive Forces Produced at Surface of Animal Membranes in Contact with Various Electrolytes, Galeotti, *Zeit. f. Physiol. Chem.*, 49, p. 542, 1904.

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Theory of Electric Excitation, Lapicque, *Comptes Rendus*, p. 1054, 1908.

Sur les effets physiologiques des courants electrique, Weiss, *Bull. Soc. internat. des electriciens*, Ser. III, Vol. 1, p. 417, 1911.

Physiological Tolerance of Alternating Current up to Frequencies of 100,000, Kennelly and Alexanderson, *Elec. World*, 56, 0.154, 1910, Same paper *Bull. Soc. belge elect.*, 32, p. 92, 1915.

2. Resistance and Conductivity

Electrical Resistance of Human Body, Hooper, *Elec. Rev.*, 38, p. 821, 1901.

Electrical Resistance of Human Body Tissues, Bordier, *Arch. d'elect. med.*, 11, p. 544, 1903.

Electrical Resistance of the Human Body, Leduc, *Arch. d'elect. med.*, 12, p. 43, 1904, and 13, p. 457, 1905.

Electrical Conductivity of Human Body, Bucky, *Elektrot. Zeit.*, 36, p. 673, 1915.

The Human Body as an Electrical Conductor, Gildemeister, *Elekt. Zeit.*, 40, p. 463, 1919.

Electrical Resistance of the Human Body, Wenner, Martin and Forman, *Physiol. Rev.*, 18, p. 141, 1921.

Effect of Coagulation on Electrical Conductivity of Blood, Samoilov, *Biochem. Ztshr.*, 11, p. 210.

Resistance of Human Body, C. M. Dowse and C. E. Iredell, *Arch. Radiol. & Electrother.*, 25, p. 33, 1920.

3. Shock and Electrocution

Electric Shocks, Aspinwall, *Jour. I. E. E.*, 31, p. 748, 1902.

Electric Shocks at 500 Volts, Trotter, *Jour. I. E. E.*, 31, p. 762, 1902.

Electric Shocks, *Jour. I. E. E.*, 31, p. 773, 1902.

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Polarization of Electrodes which may be used for Electrophysiological Purposes. Gildemeister, *Zeit. Biol. Tech. Meth.*, 3, p. 28.

Developments in Applying Electricity to Industrial Uses

By Committee on General Power Application[1]

THE annual report of the Committee on General Power Applications has been divided into three parts, namely—an account of the Committee's activities in the past year and two appendices which are believed to contain data of interest and value to the membership.

Soon after its appointment, this Committee offered its services to all Institute Sections, in the preparation of papers or in locating speakers on any subject within its scope. In answer to an inquiry from the British Consulate General, the Committee conducted inquiry into the use of magnetic hoists in shipyards and at docks, with especial reference to their effect on the ship's compass, due to its possible derangement or the magnetization of the ship's frames.

A session of the St. Louis Convention was assigned to this Committee and five papers were presented as follows:

Load-Building Possibilities of Industrial Heating, C. L. Ipsen;

A High-Frequency, Induction Furnace Plant for the Manufacture of Special Alloys, P. H. Brace;

Electrically-Heated Lead, Solder and Babbitt Pots, J. C. Woodson;

Synchronous-Motor Drive for Rubber Mills, C. W. Drake;

Use of Purchased Power in Glass Manufacture, A. L. Harrington.

The Committee has given special thought to the manner in which the wide variety of subjects under its jurisdiction may be most suitably presented to the membership. The preparation and presentation of papers alone is not sufficient. The space available in the JOURNAL and the Convention sessions which may be devoted to General Power Applications, without unduly curtailing other subjects of equal or greater importance, leave the Committee embarrassed by a too plentiful supply of new and valuable material.

As a consequence, the Committee submits as Appendix A of this report, a brief summary of progress covering important developments in General Power Applications which have come to its attention during the past year. In Appendix B is submitted a bibliography of articles which have appeared in the technical press, on subjects related to the Committee's activities. It is believed that this bibliography will be found valuable by those who wish to investigate the subjects which have been included.

The Chairman wishes at this time to record his sincere appreciation of the efforts of D. H. Braymer, member of the Committee, and also the courteous and efficient help rendered by other members of the McGraw-Hill organization. Without their assistance, the appendices would have lost much of their value.

The Committee submits the following recommendations to its successor:

a. The annual preparation of a similar summary of progress and a similar bibliography, if the reception of these by the membership indicates that they are useful and desirable.

b. Suggestion of the subject of "Group Control of Motors, Sectionalized Drive" as one which should be developed in a group of papers.

c. The recommendation of subjects on "Power Factor and Load Factor, Their Control in Industrial Applications" for special development.

The Chairman gratefully acknowledges the interest shown by the members of the Committee and the Institute Staff in their cooperation in carrying on the work of the past year.

Appendix A

A condensed summary of general progress in power applications as recorded in engineering publications during the past year.

TRENDS IN INDUSTRIAL MOTOR APPLICATIONS

Through the cooperation of engineering departments of manufacturers, consulting engineers and electrical engineers in industrial plants, progress is being steadily made along the line of more efficient power drives and control equipment and drive arrangements better suited to the changing operating conditions or tending toward lower maintenance with improved operation from the standpoint of production in manufacturing operations.

Outstanding points in this connection are, improved motor construction; modifications in motor applications to speed up production; new types of control; improved resistors; new forms of limit stops and safety features in control applications; installation of automatic equipment in steel mill substations; extended use of electric heating, and the like.

Steel Mills. The most noteworthy feature of the electrification of steel mills has been the large number of installations of new equipment that were started during a year of comparatively dull times for the steel industry. This fact is a most striking indication of the economy and reliability of electric operation.

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1. Annual Report of the Committee on General Power Application.

A. E. Waller, Chairman
A. M. MacCutcheon, Vice-Chairman

P. H. Adams,	W. B. Hall,	T. D. Montgomery,
D. H. Braymer,	H. D. James,	H. W. Rogers,
H. E. Bussey,	A. C. Lanier,	A. F. Rolf,
R. F. Chamberlain,	W. S. Maddocks,	W. H. Timbie,
C. W. Drake,		W. C. Yates.

Presented at the A. I. E. E. Annual Convention, Saratoga Springs, N. Y., June 24, 1925.

For bibliography here omitted see complete pamphlet copy.

The Westinghouse Electric & Manufacturing Company reports that five reversing equipments have been sold, including two large reversing blooming mills, two roughing structural mills and one finishing structural mill. This company further states that one of the greatest advances in the art was made this year when the company placed in operation a 500-h. p., single-unit, reversing motor, receiving its power from two 2100-kw. generators operating in parallel. It has heretofore been considered necessary to drive one motor from a single generator, and if two motors were used two generators were required. By this new arrangement it is said to be possible to design both motors and generators to best meet their operating conditions, rather than to have the design determined by the number of units of which the equipment is composed.

A 40-in. and a 44-in. blooming mill are each being equipped, by this company with 7000-h. p., single-unit motors. These are said to be the largest single-unit, d-c. motors ever built. A 500-h. p., d-c. motor is being installed by this company to operate at 155 to 500 rev. per min., at any voltage from 220 to 250. This application is for a tire mill and constitutes a speed range of 3.7 to 1, which is exceptionally high for motors of this capacity.

The Allis-Chalmers Manufacturing Company of Milwaukee, Wis., reports that it has installed and put in successful operation three mill-type synchronous motors on main roll drives of steel mills. The motors are coupled to the mills without the use of a clutch.

By the addition of 45,350 h. p. (normal continuous rating) of main roll motors during the year, the total of General Electric main roll drives has been brought to over 700,000 h. p. This company reports that an installation of particular interest is a 14-in. continuous merchant mill at the plant of the Jones & Laughlin Steel Corporation. The nine stands of this mill are driven by seven, adjustable-speed, d-c. motors. This mill will roll a very large tonnage of diversified products and the employment of individual drives with a very wide speed range is said to enable it to do the work of two or three less flexible mills.

The 26-in. rail mill at the Sparrows Point Plant of the Bethlehem Steel Company was changed over from steam to electric drive by the installation of two 3000-h. p., 500-rev. per min., 660-volt, constant-speed, induction motors made by the General Electric Company.

The Reliance Electric & Engineering Company reports that one of its most important application developments is an individual wire block driven by an adjustable-speed, d-c. motor with special automatic control equipment.

Textile Mills. An application of the brush-shifting motor to the operation of textile finishing machinery, where the operation of several motors in tandem may be required, is reported by the General Electric Company. In each case the speed of the main motor is controlled by push buttons through the operation of a pilot motor, which actuates the brush-shifting mechanism, while the speed of the other motor is controlled either mechanically or electrically by the motion of a compensating gate or floating roll between sections of the machinery.

Rubber Mills. The Westinghouse Electric & Manufacturing Company reports that for the past two years, its mill drive using synchronous motors without clutches or brakes has proved highly satisfactory. This is said to be due to the use of dynamic braking as a means of making safety stops, which has proved thoroughly reliable and effective. During the past year further improvements and developments in the control have been undertaken with a view to obtaining even greater reliability and quicker stopping. This company states that the develop nent of a three-pole, double-throw, gravity-operated contactor makes it possible to use dynamic braking with either manual or automatic starters, the braking feature being entirely independent of any external control circuit or relay operation.

The elimination of the use of low-voltage and other relays in the braking circuit, together with the use of gravity operation, is said to give a reliability exactly comparable with d-c. drive for calenders, which has been in use for so many years.

Lumber and Woodworking Mills. A variable-voltage log carriage, consisting of a d-c. motor and motor-generator set, has recently been installed on the Pacific Coast by the Westinghouse Electric & Manufacturing Co. The motor is rated at 35 h. p., and has a speed range of from 10 to 80 rev. per min. Power is supplied by a 30-kw., 320-volt motor-generator set.

The General Electric Company reports that small, drawn shell type motors of unusual speed were provided for the operation of woodworking machinery. A typical application of this character consists of five small motors with operating speeds of 25,200 rev. per min., which are utilized by a single woodworking machine, the current for the small high-speed motors being supplied by means of a frequency changer. The motors operate on three-phase, 240-volt, 420-cycle circuits.

Paper Mills. A new rotary contactor regulator for sectional paper-machine drive is reported by the Westinghouse Electric & Manufacturing Company. This regulator is an improvement over past apparatus, in that great simplicity and a more flexible action is obtained.

By the same company there has been placed in operation a paper winder drive with automatic regenerative tension control for sheets, including automatic regenerative and dynamic braking for the winder and unwinder. This is said to permit much faster operation of the winder and much better control of the finished roll, as it produces a uniform tightness throughout. Thus is avoided the expense and annoyance of frequent replacement of friction brake linings on the unwinding roll.

Also by the Westinghouse Electric & Manufacturing Company an automatic speed regulation of the vibrating regulator type for single motor paper machine drive

has been developed and placed in operation. The use of this device is said to make possible a degree of regulation not previously obtainable through inherent speed regulation characteristics of the motor and generator. This is a decided advance in the art and contributes in a marked degree to precision control, which is becoming of greater and greater importance in this industry.

An installation of a sectional paper-machine drive, for a 175-in., 1000-ft. per min., Kraft paper machine, has been placed in operation by this company. This is the largest Kraft paper machine built to date.

An installation of five automatic grinder load regulators for the control of as many 1800-h. p. synchronous motors driving pulp grinders has been placed in operation by this company. The control of the load on these machines is said to relieve the governors of the power plant of an enormous amount of work and to greatly improve the frequency and voltage regulation of the entire system.

Industrial Haulage. Induction motors designed to give a high starting torque with a relatively low current and a high efficiency when operating under load were applied for the first time to large systems of conveyers by the General Electric Company.

The first haulage electrification of an open-pit iron mine in America was effected by the adoption of three 60-ton, double-truck, 500-volt mine locomotives made by the General Electric Company at a mine of the M. A. Hanna Mining Company at Duluth, Minn. These locomotives are provided with auxiliary cable reels, and current supply is effected by means of an overhead trolley.

Machine Shops. With the improvement in cutting tools and quality of rails, has come a demand for more driving power for frog and switch planers. During the past year, the Reliance Electric & Engineering Company has developed and applied motors in sizes up to 100 h. p., 250-1000 rev. per min. to such planer drives. This company further states that reversing the motor drive with automatic control of such work means the elimination of belt troubles, ample power, accurate speed adjustments for a cutting speed range of 1 to 2, and a separate speed adjustment for return strokes from 50 to 100 ft. per min. Quick return strokes reduce the non-productive operating time to one-third that of belt drive.

A complete line of variable-voltage, reversing planer equipments has been developed by the Westinghouse Electric & Manufacturing Company. Each unit makes use of a separate motor-generator set; consequently, it is possible to install a variable-voltage equipment on a planer at any point in a plant having alternating-current service. Other outstanding features that this drive is said to have are a greater speed range, smoother acceleration and braking, and very simple control, combined with a power saving in service where reversals are frequent.

Elevators. The General Electric Company reports that radical improvements were made in the operating characteristics of its high-speed elevator equipment. One of the principal difficulties in the past has been that the speed, on any one speed position of the controller, is decidedly variable with the load, being slowest when the motor is hoisting the maximum load and fastest when the motor is being overhauled by the load. The improved system consists of a motor and motor-generator controlled on the Ward Leonard principle but with the novel feature of an auxiliary series generator by which a considerable degree of compounding can be successfully applied to the main generator to an extent entirely impracticable to apply in the ordinary manner.

A new gearless traction elevator motor for passenger service has been developed by the Allis-Chalmers Manufacturing Company. It is of the shunt-wound type designed for operation at slow speeds suitable for giving normal car speeds, using standard diameter sheaves. The system of control used is the Ward-Leonard requiring separate motor-generator set and variable-voltage control.

Elevator equipment and the necessary control has been developed to such a point of perfection that speeds of 1000 ft. per min. are now entirely possible, is reported by the Westinghouse Electric and Manufacturing Company. In fact, there seems to be no reason why speeds cannot be increased up to the limit prescribed by the speed at which humans can be transported, in vertical position, without discomfort.

Oil Wells. The Westinghouse Electric & Manufacturing Company reports that field tests of the Hild differential drive for oil wells have been made. Two holes, 3700 ft. deep, are said to have been completed successfully.

This drive is designed primarily for rotary drilling. Its function is the automatic regulation of the downward bit feed according to the resistance of the formation encountered. Essentially, it consists of a differential gear unit, two slip-ring motors and a rotary drawworks. One of the motors—the drill motor—drives the rotary table which revolves the drill pipe and at the same time drives one-half of the differential. The other—the regulating motor—drives the other half of the differential. The two motors operate the differential in opposite directions, the operating motor in a direction tending to raise the drill pipe and the drilling motor in a direction tending to lower it. By adjusting the speed of the drilling motor slightly higher than that of the regulating motor, a slow downward feed of the drill pipe is produced. If the resistance to the drill is increased due to change in formation, the increased load slows down the drill motor and a slower feed results. Conversely, a lighter load means a more rapid feeding of the bit. High resistance encountered in drilling through hard rock causes the bit to rise until it clears itself.

Automatic Controllers. Because of the very nature of industry and the years of study of application and performance of motor devices and control, there is always a

certain amount of development and refinement in controller design and construction that is accomplished through the increased knowledge of the requirements of industrial power drives. The year 1924 was no exception with regard to progress and developments.

One of the outstanding developments is the inductive, time-limit controller devised by The Cutler-Hammer Manufacturing Company of Milwaukee, Wis. In the design of this time-limit starter the inductive principle is utilized to obtain the accelerating time, a transformer being used in place of relays, interlocks, dashpots or other moving parts to control the time of acceleration. The manufacturer states that, through the medium of the transformer, a holding-out current of transient nature is obtained in successive accelerating switches. Transfer of connections takes place automatically with the cutting out of successive steps of resistance without disconnection of the coil circuits. It is said that in this new development, the acceleration period is very uniform under ordinary conditions of load variations, the time being somewhat increased on heavy loads; thus the machine driven, whether reversing table, screw-down or other auxiliary machine, is always brought up to speed in the same period to insure the productive synchronism and plant efficiency desired.

Another development in time-limit acceleration is reported by the General Electric Company in the case of a 300-h. p., a-c. motor on the hoist and a 75-h. p., a-c. motor on the trolley of a coal tower at Clairton, Pa. Current-limit acceleration was previously used on this application and the change to time-limit acceleration was secured by using a suitable number of d-c. contactors and allowing them to close in sequence, each one being interlocked through the preceding contactor. D-c. contactors were used to secure a slow time of closing, so that fewer contact elements were required than would have been necessary with alternating-current contactors. No time element relays were used.

Two forms of resistor-type magnetic starters for a-c. motors have been produced by the General Electric Company; one for squirrel-cage induction motors, and one for slip-ring motors. Mechanically, these starters are very much alike, the difference being chiefly in their connections. They both employ a new type of time-element relay for the accelerating period, which can be adjusted to about six seconds. The relay consists of an armature that is drawn across the face of an a-c. magnet by a spring which is distended when the line contactor closes. The magnetism resulting from the alternating current intermittently attracts and releases the armature as it slides by the pole face, thus giving the desired time adjustment.

A great advance has been made in the control of blooming mill auxiliaries, by the installation of two entirely separate control circuits, either of which can be used at will, is the report received from the Westinghouse Electric & Manufacturing Company. Each master switch is plugged into a receptacle, and in case of trouble can quickly be replaced by a spare. A complete spare control panel is included which can be quickly transferred to any motor.

Similar information comes from the Rowan Controller Company of Baltimore, Md., in citing the case of a switchboard containing the necessary control equipment for the auxiliaries for a large blooming mill in the Cleveland steel district. A unique feature of this installation is that all the controllers for the front and rear tables and the screw-down are exactly alike. An additional spare control panel is provided so that by means of throwover switches this spare panel can be rapidly connected in place of any of the other similar controllers.

A new type master has been developed by the Cutler-Hammer Manufacturing Company for use particularly with Cutler-Hammer magnetic-type controllers. This master is a compactly enclosed structure with a contact cylinder mounted on a square shaft. Standard non-stubbing contact fingers such as are used in Cutler-Hammer drum controllers, are mounted on the stationary support, the leads to which they are connected also remaining stationary. Pyroplax arc barriers are placed between the fingers and the contact segments which are automatically lubricated by means of an oil wick which holds sufficient oil for about six months use.

A new automatic reversing planer controller has been developed by this company. The scheme of control employed plugs the planer motor in stopping and reversing the planer, and the company reports that this results in the fastest method of operation. Two shunt-field rheostats are provided in the control—one is for regulating the cutting speed and the other is for adjusting the return stroke speed.

For several years past it has been evident that the trend of safety regulations is toward the enclosure of all types of motor starters and speed controllers. During the year, the General Electric Company reports that work along these lines was practically completed, and the remaining open-type starters and speed controllers were provided with either self-contained enclosing cases with external handle or were redesigned to accommodate enclosing cases when required.

Monitor Thermaload starters, manufactured by the Monitor Controller Company, Baltimore, Md., are now being built with standard Monitor side-arm contactors instead of the special contactor previously employed. Hairpin-shaped thermal elements are also being supplied, instead of the coiled elements previously used.

The thermal relay of the Monitor Thermaload starter operates on the thermal expansion principle. The heat produced by the thermal element under overload causes a liquid confined in a tubular receptacle to expand and to elongate two expansion units. These expansion units in turn operate an arm containing two contacts which control the operating circuit of the contactor. The liquid used is carbon tetrachloride, a non-corrosive and non-freezing liquid which is used extensively for fire extinguishing purposes. This starter is intended for starting small induction motors, both single-phase and polyphase, and is said to protect the motor

against light overloads dangerously prolonged, yet permits the motor to carry heavy overloads momentarily.

A new steel enclosed, dust-proof drum controller is being marketed by the C. H. McCullough Engineering Company, of Pittsburgh, Pa. This company reports that the diameter of the drum of this controller is exceptionally large, giving a greater wearing surface and thereby increasing the arcing distance between points. This company also points out that due to its dustproof qualities the controller is especially adapted to foundaries, steel works, cement plants and similar dusty locations.

The Condit Electrical Manufacturing Company has announced that during 1924 it has arranged its type N-3 oil motor starters for push-button control, thus making them especially adaptable to industrial service. The type N-4 starter which was developed in 1923 is now equipped with thermal cutouts.

The Allen-Bradley Company of Milwaukee, Wis., has within the last year or so added refinements to its lines of across-the-line starters, automatic starters and semi-automatic starters, according to reports received from them. It also informs us that these lines have been standardized so that they can be made on a large quantity basis at a very reasonable price and yet keep the same standard of quality for which these starters have been noted.

Heretofore, fractional horse-power motors have, to a very large extent, utilized standard, wiring device switches, which were primarily designed for lighting circuits. A new design of single-pole and double-pole enclosed tumbler switches, assembled in boxes for conduit wiring for throwing small motors on the line, now gives these motors a class of control equipment comparable with that provided for large motors, reports the General Electric Company.

This company also informs us that a new thermal overload relay was designed to follow the heating and cooling curve of the average induction motor, and that this is particularly adapted to service where it is important for the motor to carry heavy, short-time overloads intermittently, without being tripped out by the overload device. It is said that this device will permit the motor to do any kind of work that does not run it above a safe operating temperature.

The company states that it has developed a definite time relay which was utilized for the first time in an automatic compensator, and is now used to provide the accelerating period. It consists essentially of a motor-driven train of gears, magnetic clutch and switching mechanism to provide for either opening or closing the contacts at the end of the time for which the device is set, being adjustable from a few seconds up to several minutes, and adaptable to many applications where a definite time adjustment is needed.

The Cutler-Hammer Manufacturing Company states that a complete line of control equipment for various sizes of Fynn-Weichsel, alternating-current motors (made by the Wagner Electric Corporation, St. Louis, Mo.) was brought out in 1924. For the smaller sizes, the face-plate type with the operating handle arranged for manipulating from the exterior of the enclosing case is used. A drum type starter is employed with the larger motors incorporating in its design non-stubbing fingers, a square steel shaft for carrying the contact segments, and blowout shields. In all of these starters the design takes care of simultaneously cutting out resistance in each of the two secondary windings found in this type of motor.

For the automatic control of motor-driven pumps, air compressors and the like, the General Electric Company has developed a new pressure governor for use in connection with automatic starters. This governor is of the Bourdon tube type, and can be used on any liquid or gas system which will not corrode the Bourdon tube. The equipment includes an "impulse" magnetically operated relay of a quick throwover type breaking its own operating circuit as soon as it functions.

Three, across-the-line, automatic starters have been placed on the market by the Sundh Electric Company of Newark, N. J., one having undervoltage release or undervoltage protection, the second in addition, having, inverse-time-limit overload thermal relay protection and the third being provided with inverse-time-limit overload relay protection. All these starters are manufactured in either the open or enclosed type, two-pole or three-pole, for motors up to and including 10 h. p., 220-440-550 volts.

Heretofore this company's principal activities have been more or less confined to furnishing control for large office buildings and pump concerns. This company now plans to enter the industrial market more intensively with the present line of equipment rounded out with the additions that have just been described.

Compensators. Two new automatic compensators have appeared on the market during the past year. One of these is a high-voltage compensator made by The Electric Controller & Manufacturing Company of Cleveland, Ohio. It is built for voltages of 2500 and below, is push-button operated and entirely automatic. With the exception of the overload panel, which is mounted on the top of the tank, the compensator is entirely submerged in oil and the tank is so designed that the compensator is said to be dustproof, weatherproof, vaporproof and fireproof. It may be installed either indoors or outdoors.

The power supply for the push-button circuit comes from an independent low-voltage circuit which is taken from a separate transformer so that there is no danger of the operator ever coming into contact with the high-voltage circuit. The compensator is so designed that continuous torque is applied to the motor from the time the push-button is pressed until the motor has been brought up to speed.

A new automatic starting compensator for squirrel-cage induction motors, has been placed on the market by the General Electric Company. This motor starter

is for remote control of constant-speed, two- or three-phase, squirrel-cage motors up to 600 volts and general applications driving lineshafting, pumps, compressors, blowers, conveyors and the like. With it, such equipment may from a distance be started or stopped by means of one or more small hand-operated push buttons or snap-switches located within convenient reach of the operator or automatically operated by a pressure governor, float switch, thermostat or similar arrangement.

Resistors. A ribbon-type resistor, wound on edge, has recently been developed by the Monitor Controller Company, Baltimore, Md., and is intended for service where cast-iron grids would otherwise be employed. It consists of a high-resistance alloy ribbon, wound on edge in helical form and mounted on a steel-reinforced, porcelain support which passes through the entire length of the unit, supporting and separating every convolution at two diametrically opposite points. This method of construction relieves the resistor ribbon from mechanical strain and permits of thorough ventilation. The maker states that the ribbon will operate at any temperature up to red heat without sagging or in any way injuring the resistor as a whole.

A system of terminals and taps enables a unit to be connected into a circuit, and to be interconnected with other units. Two simple forms of clamps provide all these facilities. These clamps may be placed at any desired point along the resistor and changed at will. This permits of accurate adjustment of the resistance steps. The maker reports that a saving of weight and space is obtained by the use of these resistors as compared to cast-iron resistors. These resistors are shown in an accompanying illustration.

The *EMB* grid resistor, manufactured abroad, is being introduced by the C. H. McCullough Engineering Company, of Pittsburgh, Pa. This resistor is made of drawn material and in one continuous length for an amount equal to one frame, or bank. The maker states that it is unbreakable, rustless, scaleless, of uniform section, jointless in the frame and is covered by a five-year guarantee. He also states that the weight of same is less than that of cast-iron grids of equal rating.

Safety Switches. A new, small safety switch has been placed on the market by The Trumbull Electric Manufacturing Company, of Plainville, Conn. This switch is now made in the 100-ampere, 250-volt size and will shortly be made in the 440- and 550-volt size. The maker reports that the switch is characterized by its small size, yet the parts are accessible since the switch may easily be removed from the box. The switch is constructed on the double-break principle, the blades being carried on a rotor made of molded material.

A new line of quick-make, quick-break, enclosed safety switches has recently been put on the market by the Westinghouse Electric & Manufacturing Company. This line was designed to meet the demand for a simplified enclosed switch without the full safety features.

This switch, known as the WK-60 switch, is unique in that the quick operating mechanism has been condensed into a few simplified parts, located inside the operating handle. The maker states that this feature alone is a marked advance in the design of safety switches, since it lends greater reliability, lesser maintenance cost, and at the same time, increases the ease of plant operation with regard to inspection testing and the making of repairs.

A new "Lumenized" finish has been added to the line of Bull Dog safety switches made by the Mutual Electric & Machine Company of Detroit, Mich. The company states that this finish involves the depositing of aluminum flakes, like tiny fish scales, upon the basic metal under high temperature. It is said that the result is giving the switch the following qualities: making it luminous in the dark; rust, acids, and alkalies resisting; easily grounded; and the last word in cleanliness.

A new type of cross-bar construction has been incorporated in safety switches made by the Square D Company of Detroit, Mich. A steel bar is heavily insulated with molded composition tubes, possessing not only superior mechanical strength but greater dielectric strength as well. This construction has an extremely low absorption of moisture, which is said to prevent warping and the consequent distortion of blade alignment. Wide fiber washers have been provided to prevent accumulation or adherence of dust, breaking up any continuous path of dust to ground. The insulating tubes have an offset at the ends so that dust cannot work in under the washers, thus causing leakage.

During the past year the Super-Safety Electric Company has developed a new design of safety switches of the larger sizes. Instead of the contacts being on the base of the cabinet, as is usual, they are placed on sides of the cabinet, thus leaving the base entirely clear. This constitutes the principal difference between the new switch and the more usual types of safety switches.

The maker reports that this type of construction results in the following advantages; greatly increased wiring space within the switch with, at the same time, a reduction in overall dimensions; double break—a break on each side of the fuse; greater flashover distance between polarities; and perfect and even contact between all contact members by reason of their tandem arrangement and their self-alining construction. This switch is shown in one of the accompanying illustrations.

Limit Switches. A new safety limit stop has been developed by The Morgan Engineering Company, Alliance, Ohio. This device consists of a cast-iron box in which are mounted two double-throw, single-pole switches. These two switches, when actuated by contact with the hook block, cause the limit switch to function. The maker states that this limit switch differs from others in that a resistance is thrown in series with the armature as the limit switch starts to function, thereby slowing down the armature and greatly reducing the amount of current broken by the contactors. Complete stopping of the hoist motor is accomplished by an usual arrangement of dynamic braking. The maker also points out that another feature of this limit switch is that the lowering circuits

are established immediately upon the reversal of the controller through the action of a solenoid; there is no waiting to lower through resistance. Other features cited by the manufacturer are: absence of external banks of resistance, for the limit switch is self contained; positive action, since an upward movement of the weight of even a fraction of an inch will actuate the limit stop; foolproof, having only one adjustment; the use of extra large copper to carbon contactors; having only one swinging weight, guided by one of the hoisting ropes; and sequence of operation of the contactors obtained by a single system of levers, with no cams, springs or counterweights.

The Cutler-Hammer Manufacturing Company of Milwaukee, Wis., reports a new development in safety limit stops which is said to be a compact, rugged unit with a number of features of great importance in the functioning of a safety device. The working parts are liberally designed and arranged to move freely, this ease of operation being still further insured by the provision of ball bearings.

Miscellaneous. A new quick-acting, electric, solenoid brake has been developed by the Whiting Corporation of Harvey, Ill. This brake was especially designed for application to crane service.

The maker points out that the brake arms are so pivoted that the shoes release equally at all points; leaving no chance for shoes to drag at the lower ends. This is said to be a great advantage in applying the brake as the shoes bear equally at all points, resulting in quick braking action as well as uniform wear.

Nichols-Lintern Company of Cleveland, Ohio, reports improvements in its electromagnetic sander. An electrically-heated chamber has been placed around the sand box, thus keeping the sand warm and dry, thereby greatly increasing the efficiency of the sander. These sanders are intended to replace dangerous and wasteful hand sanding methods and are said to save crane and runway maintenance.

The use of static condensers for power-factor correction in industrial plants has increased considerably. The Westinghouse Electric & Manufacturing Company reports that it has developed a new low-voltage unit which may be connected at the motor or place where the power is used, thereby reducing the line losses in the feeder circuits. This new line of low-voltage condensers is made for 220-, 440-, and 550-volt, 60-cycle service.

The National Electric Condenser Company of New Haven, Conn., is also putting out a line of low-voltage condensers for direct connection at the motor terminals.

Automatic Substations. The automatic station has become firmly established as an economic, operating necessity in the electrical industry. With its inherent advantages established beyond dispute a marked advance in the application of this type of control was made during 1924.

There were no radical changes in the design of automatic switching equipments. The tendency during 1924 was to produce unit equipment which might be easily handled and installed, standardizing wherever possible. The General Electric Company reports the progress of standardization to such an extent that complete automatic stations for mining and industrial service are now being stocked.

To meet the requirements for this class of service, the company states that one type of standardized design is so arranged that a single machine automatic control equipment may be used in either single- or multiple-unit stations with any number of reclosing feeders, thus giving maximum flexibility, since it allows of arranging converting units in any manner desired with a possibility of later re-arranging if called for by a change in load conditions. This may then be accomplished without modifications of the control.

Theater Dimmers. A combination stage dimmer and switchboard termed "Controlite" has recently been developed by the Ward Leonard Electric Company. A quick make and quick break switch opens the circuit after the lights are dimmed. This simplifies the control of the lights by reducing the number of movements which the operator has to make. It has previously been considered good practise to dim the lights with one lever and reach elsewhere on the switchboard to open the switch.

Space on the stage is limited and the control handles have frequently been placed eight and nine feet from the floor. *Controlite* by its simplification makes it possible to place all operating handles within easy reach of the operator.

Motor Driven Dimmers. There has been an increasing demand by the trade for motor driven remote controlled dimmers to control the lights in the auditoriums of moving picture theaters, churches and masonic halls. The Ward Leonard Electric Company has developed several very efficient types of motor drive for their dimmers.

Control Equipment

A new line of motor and generator field rheostats has been completed by the Ward Leonard Electric Company. The smaller sizes are of the Vitrohm (vitreous enameled) type and the larger capacities are of the "Ribohm" (stamped metal grid type). Due to new developments in the art of enameled rheostat construction, the Vitrohm plates are made of stamped steel, instead of being of the former cast iron construction. Many advantages are claimed as a result of this change.

This company has also recently placed a dead-front type sectional battery charging panel on the market. It is especially adapted for charging electric vehicle batteries. The special features are compactness, ease of operation, and the total enclosure of all live parts. A unique design of enclosing cover renders all operating parts readily accessible when necessary.

The Ward Leonard Electric Company has also produced a line of totally enclosed contactor type motor starters which are unique in that the resistors form part of the enclosing case but are arranged so that all heat radiation takes place outside of the enclosure.

Universal Type Motors

BY L. C. PACKER[1]

Associate, A. I. E. E.

***Synopsis.**—Heretofore the subject of universal motors has not received very much publicity but the field for these motors has been increasing so rapidly that a great deal more attention is now being given to them.*

The paper endeavors to bring out points of general interest rather than going into the fundamental design and other details.

The term "universal" as applied to this type of motor is defined, together with a description of the operating characteristics in general.

There are two types of universal motors; namely, compensated and non-compensated, both of which are described as to general design, construction and applications.

The question of ratings and limitations of the universal features of both types of motors brings out some interesting points.

Commutation and mechanical balance are questions demanding a great deal of attention due to the comparatively high speeds at which these motors usually operate.

Some of the applications best suited to the universal motor are described, showing the possibilities of this type of motor when properly designed, manufactured and applied.

* * * * *

THE term "universal" is applied to certain small series-wound motors, the performance of which is almost identical when operated on either alternating or direct current. (Alternating current is used in this paper to mean frequencies of 60 cycles and lower.) Universal motors have been in commercial use for fifteen or more years and are still most popular in the two applications in which they were first used in quantities; namely, portable drill and vacuum cleaner drive. However, with improvement in the motors and increase in the number of small motor driven appliances, a number of new fields for the application of these motors are being found. If a manufacturer's product is sole over a large area, it is obviously to his advantagd to use a motor which will operate equally well on either alternating or direct current, and only the voltage of the circuit need be considered. This advantage has led some appliance manufacturers to modify their machines so that the operating characteristics of universal motors will be satisfactory for driving them.

All of the universal motors on the market are series wound and their performance characteristics are very much like those of the usual type, d-c. series motor. The no-load speed is quite high but seldom high enough to damage the motor, as is the case with larger d-c. series motors. When a load is placed on the motor, the speed decreases and continues to decrease as the load is increased. Although universal motors of several types of construction are manufactured, they all have the varying speed characteristic just mentioned.

Due to the difficulty in obtaining like performance on alternating and direct current from motors designed for operation at low speeds, most universal motors are designed for operation at speeds of 3500 rev. per min. and higher. Motors operating at load speed of 8000 rev. per min. to 10,000 rev. per min. are common. Practically all portable vacuum cleaner motors come within this range. Working speeds above 10,000 rev. per min. are not so common, due to there being few applications where such speeds are desirable and to the manufacturing difficulties in producing motors which will run at such speeds. Small stationary vacuum cleaners, truck-type vacuum cleaners and the larger size of portable tools have motors with operating speeds of 3500 rev. per min. to possibly 8000 rev. per min.

Ratings from zero h. p. to one h. p. are being manufactured. However, it is not possible to obtain the very low h. p. ratings at the lower speeds and get the same performance when operating over the whole range of frequencies from direct current to 60 cycles. In other words, the motors designed for very low horse powers and the lower speeds cease to be universal, for although they will operate on either alternating or direct current their speed for a given load varies over too wide a range with changes in the frequency of the supply circuit.

It is not possible to set a definite limit of difference in speed for a given load, inside of which a motor may be said to be universal and outside of which it would not be designated as universal when motors are operated on direct current or on various frequencies. That is, it cannot be said that when operating at rated load, the variation in speed must not be more than 10 per cent, 15 per cent or 20 per cent, if the supply circuit is changed from 60 cycles to any lower frequency or to direct current. In the usual universal motor applications, such speed variations will probably be found. However, in any application, the motor is considered as being "universal" if it will operate the apparatus satisfactorily when the power supply is varied over the entire range of commercial frequency with rated voltage applied in each case.

Vacuum cleaners and portable drills are two examples of very satisfactory applications for universal motors. In both of these applications, the variation in performance when operating on varying frequencies, can easily be kept within the required limits and it is desirable to have the speed vary with the load. If a vacuum cleaner is used under conditions which decrease the volume of air handled, the load on the motor is decreased and the speed increases. The increase in speed increases the vacuum, causing the cleaner to handle more air than it would if driven by a constant speed motor. Portable drills are almost ideal applications for universal

1. Westinghouse Electric & Mfg. Co., Springfield, Mass.

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motors. The cutting speed is automatically adjusted by the load, since the smaller the size of the drill being used the lighter the load and consequently the higher the speed, and vice versa, when larger drills are used.

The same conditions exist when universal motors are used in small pipe-threading machines and in certain other metal and woodworking machines.

The speed of a universal motor can be adjusted by connecting a resistance of proper value, in series with the motor. Advantage is taken of this characteristic in such applications as motor-driven sewing machines, where it is necessary to operate the motor over a wide range of speed. In such applications adjustable resistances are used and the speed is varied at will.

When considering the use of universal motors to drive any apparatus, the following characteristics of the motor should be considered:

Change in speed with change of load

Change in speed with change in frequency of power supply

Change in speed due to change in applied voltage.

The last item has not before been referred to except indirectly in connection with the use of series resistance to adjust the speed. However, a larger percentage of all small motors is connected to lighting circuits and the voltage conditions are not always of the best. This condition must be kept in mind when determining the proper motor to use for any application regardless of type. In general, the speed of a universal motor varies directly as the voltage.

The starting torque of universal motors is usually much more than that required and in most applications does not have to be considered.

There are some motor applications where the motor runs all of the time and the load is connected and disconnected by means of a clutch. On such applications, if the operating characteristics of a universal motor are satisfactory while the load is applied but the no-load

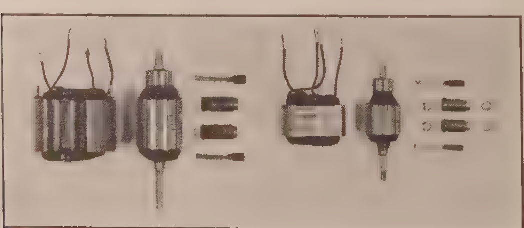

Fig. 1

speed is too high, it is sometimes possible to arrange to have a series resistance connected in the line during the time the clutch is in the position to release the load. The value of this resistance can be made such as to give the desired no-load speed.

Universal motors are applied with two kinds of construction—(1) concentrated-pole, non-compensated and (2) distributed-field, compensated. Most motors of low h-p. rating are of the concentrated-pole, non-compensated type, while those of the higher ratings are of the distributed-field, compensated type. The dividing line is somewhere near 1/4 h. p., but the type of motor to be used is determined by the severity of the service and the performance required. All of the motors have wound armatures of the same construction as the ordinary d-c. motor.

The concentrated-pole, non-compensated motor is exactly the same in construction as a d-c. motor except

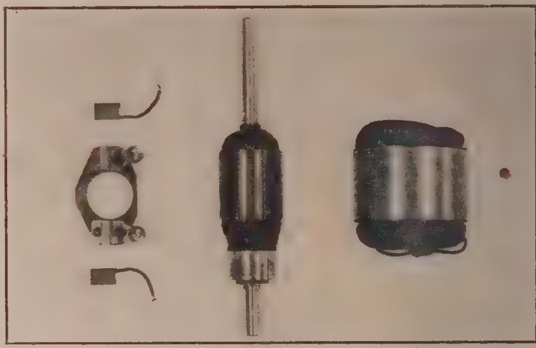

Fig. 2

that the complete magnetic path is made up of laminations. The laminated stator is made necessary because the magnetic field is alternating when the motor is operating on alternating current. The stator laminations are punched with the poles and the yoke in one piece. This makes a very simple construction and one which is very satisfactory to the appliance manufacturers who buy the motor parts as shown in Fig. 1, and assemble them in their apparatus.

The compensated type of motor has stator laminations of the same shape as those in an induction motor. These motors have stator windings of one of two different types. The parts of a compensated motor, as they are supplied to be built into the apparatus, are shown in Fig. 2.

The question might naturally arise as to why it is desirable or necessary to have the non-compensated and the compensated motors and why the ratings are usually limited to fractional horse powers and high speeds. The non-compensated motor is more simple and less expensive than the compensated motor and would be used exclusively over the entire range of ratings if its performance were as good as that of the compensated motor. However, as before stated, the non-compensated motor is used for the higher speeds and lower horse power ratings only. Figs. 3 and 4 show the speed-torque curves for a compensated motor and a non-compensated motor, respectively. It will be noted in Fig. 3 that although the rated speed is relatively low for a universal motor, the speed-torque curves for various frequencies lie very close together up to 50 per cent above the rated torque load. In Fig. 4, the performance of a much higher speed, non-compensated motor is shown. For most universal motor applica-

tions, the variation in speed at rated loads as shown on this curve is satisfactory. However, the speed curves separate rapidly above full load. If this motor had been designed for lower speed, the tendency of the speed-torque curves to separate would have been more pronounced. The chief cause of difficulty in keeping the speeds the same is the reactance voltage which exists when the motors are operated on alternating current. Most of this reactance voltage is produced in the field windings by the main working field. However, in the non-compensated motor some of it is produced in the armature winding by the field pro-

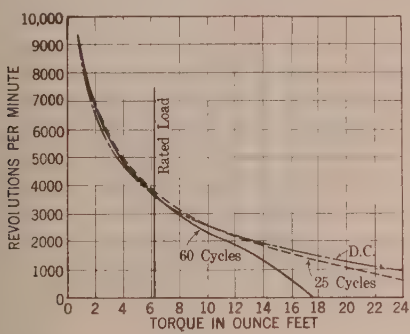

Fig. 3—Universal Motor Compensated ¼ H. P.—3400 Rev. Per Min.

duced by the armature ampere-turns. The true working voltage is obtained by subtracting the reactance voltage vectorially from the line voltage. If the reactance is high, the performance at a given load will be the same as though there were no reactance

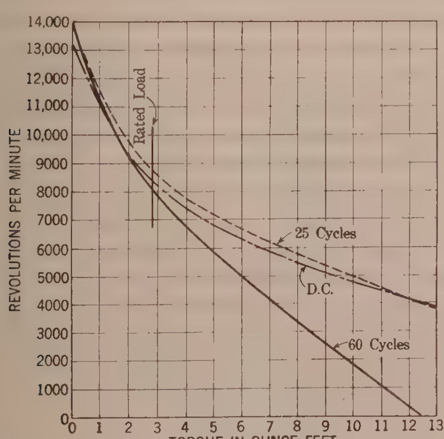

Fig. 4—Universal Motor Non-Compensated ¼ H. P. 800 Rev. Per Min.

voltage and the applied voltage had been reduced with consequent reduction in speed.

The reactance voltage varies with the frequency and is almost entirely responsible for the difference in performance on the different frequencies of alternating current. However, the difference in performance, when operating on alternating current and when on direct current, is caused not only by reactance voltage but also by the difference in the amount of flux produced by a given value of direct current and by the same value of alternating current. Due to the saturation of the iron in the magnetic path at the time of the maximum value of the alternating-current wave, the alternating current does not produce an effective value of flux equal to that produced by an equal value of direct current. While the reactance voltage reduces the speed, the reduced flux on alternating current increases the speed. The reactance voltage varies with the frequency, but the flux for a given value of alternating current remains constant, regardless of the frequency. When the motor is operated on low frequency the effect of reactance is almost negligible, while the reduction in flux is just as high as for the higher frequencies. The result is that on very low frequencies the speed is always higher than when the motor is operated on direct current. It is even possible to have conditions such that the speed on 60 cycles is higher than that on direct current. However, the latter condition can seldom be obtained in a motor design which is satisfactory in other respects.

It is now apparent that, to get like performance on alternating and direct current, the reactance voltage must be low and the difference between the flux on direct current and alternating current must be decreased wherever possible. The difference in magnetic flux produced by a given value of direct current and that produced by an equal value of alternating current, can be changed only slightly by changes in the material used or in the design of the parts. The reactance voltage can be reduced or increased within certain limits by changes in design. As mentioned before, the major part of the reactance voltage is produced by the field flux passing through the field winding. By keeping the product of the field turns times the flux to a low value, the reactance can be kept proportionally low. This results in what is usually termed a "weak field" motor. Now a weak field in an ordinary d-c. motor permits the field to be distorted by the ampere-turns in the armature, resulting in a tendency towards poor commutation and greater changes in speed with a given change in load. Identical conditions exist in a concentrated pole, non-compensated, universal motor. However, it is necessary to keep the reactance voltage low to prevent the speeds from becoming too low on the higher a-c. frequencies. Within a certain range of speed and h-p. ratings, the reactance voltage can be made low enough to keep the speed variation within reasonable limits and at the same time secure satisfactory performance from the motor. Much has been done in the matter of improving the commutation of weak field motors by improvement in the grades of carbons and by better motor design. When, in a desired rating, the horse power is too high or the speed too low to obtain satisfactory operation with a non-compensated motor a compensated motor is used.

In the compensated motor there is a series winding having a magnetizing force equal and opposite to the magnetizing force of the ampere-turns in the armature. This tends to eliminate field distortion and the resulting bad commutation. When the field distortion has been eliminated, a very weak field can be used with a resultant decrease in reactance voltage and the corresponding decrease in variation in speed for change in frequency. Due to mechanical reasons, it is impossible to distribute the compensated windings so as to exactly compensate for the ampere-turns in the armature. It is this lack of exact compensation which limits the horse power and speed to be obtained in the compensated type of universal motor.

Two types of stator windings are used in the compensated motor: In one type, two distinct field windings are employed. The compensating winding, which has just been referred to, is equal and opposite to the effective ampere-turns in the armature and is distributed to correspond to the armature winding. The main field winding is located 90 electrical degrees from the compensating winding and produces the working field. This winding usually occupies just two slots per pole. In the other type of field winding but one distributed winding is used. By shifting the brushes to the proper position, the armature ampere-turns are opposed by a certain portion of the field ampere-turns and the remaining portion of the field ampere-turns produce the working field.

When the two-winding type of stator winding is used, the brushes are located on the neutral with reference to the main field winding. This permits the direction of rotation to be reversed by reversing the main field. When assembling this type of motor, the brushes can easily be set in the proper position by applying alternating current to the compensating winding and operating the motor as a repulsion motor by short circuiting the brushes. When the brushes are so set that the armature field is directly opposite the compensating field there will be no tendency in the armature to rotate. When the brushes are moved slightly from this position, the armature will turn in the direction in which the brushes have been moved. The brushes are in the correct position when the armature field is directly opposite the compensating field.

When designing a motor using the one-winding type of stator winding, if certain limiting proportions of field and armature turns are adhered to, it is possible to get exactly the same conditions as to compensation and main field as is obtained when using the two-winding type of stator winding. However, due to the restrictions in regard to relative strength of armature and field, it is difficult to get complete compensation for certain ratings. The fact that the brushes are located off of the neutral of the field winding makes it necessary, in order to get compensation, to shift the brushes when the direction is changed. This makes this type of motor unsatisfactory for reversing service.

The two most difficult problems in the manufacture of these high speed motors, is that of obtaining good commutation and good mechanical balance. In addition to these, it is necessary to have all parts of the armature well made so that they will withstand the larger centrifugal force which is present when the motor is operating at the high speed to which it will be subjected.

Aside from the usual commutating conditions which are encountered in the ordinary d-c. motor, there is a transformer voltage generated in the short-circuited coil by the alternating main field flux. This transformer voltage is one of the chief causes of commutation trouble, and poor mechanical balance causes sparking at the commutator due to the inability of the brushes to make good contact with the commutator when the armature is vibrating at high frequency. In addition to this it will be realized that, in motors running at speeds around 10,000 rev. per min., the time permitted for the current to reverse in the coil while it is being commutated, is very short. In an ordinary vacuum-cleaner motor, this reversal of current in the coil being commutated must be accomplished in one-half of 1/1000 of a second. The fact that the coil is short circuited for such a short time determines, to a certain extent, the amount of short-circuit current which exists in the coil.

When considering the mechanical balance, the unusual speed of these motors must be kept in mind. Referring again to the ordinary vacuum-cleaner motor, we find that the centrifugal force acting on an object at the surface of the armature when the motor is operating at normal speed, is approximately two thousand times the weight of the object. As an example, if a piece of No. 20 wire, 1½ in. long, were placed at the top of the armature slot, the centrifugal force acting on the wire would be equal to the total weight of the armature. With this in mind, it is quite obvious that the weights in the armature must be thoroughly balanced or there will be excessive vibration and excessive pressure on the bearings. The usual static balance of armatures improves any unbalance that may exist due to the uneven distribution of the windings or due to there being a slightly heavier coat of armature insulating varnish in one place than in another. However, if when balancing an armature statically the correction of weight is made at the end of the armature opposite that at which the unbalance exists, there is still a very bad condition of dynamic unbalance which will be destructive to bearings and brushes and cause the motor and driven appliance to be noisy. This condition can be eliminated only by very careful dynamic balancing.

The results which may be obtained by using extreme care in designing and manufacturing are shown by tests made on a particular vacuum-cleaner motor. This motor was so designed, electrically, as to get the best commutating conditions, and accurate dynamic balance was obtained. At the end of a 5000-hour endurance run, the indicated total brush life for one set of brushes was 9000 to 10,000 hours. As stated, this motor was very carefully built and such motors could not be produced commercially due to the increased manufacturing

cost. However, the tests on this motor did show the results of careful design and dynamic balance. There is no need in vacuum-cleaner service for a motor such as the one described. If a vacuum cleaner were used continuously two hours per week, which is probably the average, the total hours run per year would be approximately one hundred and the total life of one set of brushes would be 100 years. It is quite obvious that it is not necessary to go to the expense of building a motor of this quality when it is impossible for the driven appliance to remain in service such a great length of time. However, it must be remembered that the brush

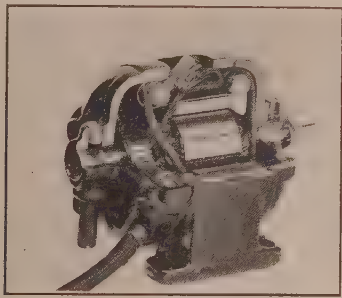

FIG. 5

life which has ordinarily been obtained in vacuum-cleaner motors has not been equal to the life of the vacuum cleaner. The vacuum cleaners being built today are of better quality than those of several years ago and are standing up better, with the result that better motors must be supplied. It is such tests as the one just mentioned which are pointing the way to better motors and are actually bringing about results in the commercial motors now being supplied for vacuum-cleaner service.

Vacuum cleaners and portable drills have already been mentioned as very satisfactory applications for universal motors. In addition to these, there are many other applications in which universal motors are being used. In many cases, the motor parts are supplied to the appliance manufacturers and built into his appliance. In other cases, complete motors, such as the one of which a partcross section view is shown in Fig. 5, are used to drive the appliances. Some of the devices to which these motors have been applied are advertising machines, portable, motion-picture machines, dish washers, hair clippers, sewing machines, drink-mixing machines, small ventilating fans, hair driers, pipe threaders, small grinders and small wood shapers and routers. This is a rather varied list of applications and the variety and number of applications are growing daily.

Discussion

W. L. Smith: I wish to emphasize the fact that on these little motors there is one thing that I believe is very important and that is that the greatest care should be given to perfection in insulation.

H. W. Hills: We can't blame the insulation for all trouble, for, because of the way these machines are used, the insulation becomes oily and hard and even the best insulation, after being subjected to such conditions, will eventually fail. The only thing to do is to provide a good ground on the machine itself. This can easily be done by incorporating a third wire for a ground wire along with the two supply wires. This ground wire can be attached to ground while the machine is in operation.

L. C. Packer: Recently the underwriters have specified insulated brushholder screws for commutator motors. That is a point that the appliance manufacturers have stressed a good bit, and the underwriters have specified certain design points that must be adhered to. Insulation of brush-holder screws is one very important item, especially in vacuum-cleaner and sewing-machine motors.

There is another point about the insulation. Most of the manufacturers of this type of motor test to ground at 1200 or 1400 volts, on a standard 110-volt motor. The motor itself is just as well insulated as higher types of motors. Most of the grounds are caused during the assembly of parts by the appliance manufacturers in grounding the connections against the frame: sometimes the insulation is pinched off the leads in assembly.

C. A. Adams: I should like to ask Mr. Packer how he can get substantially 100 per cent power factor.

L. C. Packer: In the compensated motor the field is usually fairly weak and its reactance voltage comparatively low; that is, from 10 to 20 volts on 25 cycles at rated load. The equivalent values on 60 cycles are 24 to 48 volts. The average motor of course will have about the average value between these figures. For illustration in an average design the reactance voltage due to the field is 15 volts on 25 cycles, and 36 volts on 60 cycles. Then suppose we work the motor over a range of load such that the value of reactance voltage would be from 10 to 20 on 25 cycles, and from 24 to 48 on 60 cycles. Since the reactance voltage varies directly with the flux, these values represent considerable change in load.

Since the true working voltage is the vectorial difference between the line and reactance voltages and since the power factor is equal to the true working volts divided by the line volts, it can be seen that it takes quite a material change in reactance voltage to show much change in power factor and it also takes a comparatively large amount of reactance voltage to drop the power factor an appreciable amount below unity.

As a rule, the power factor of the non-compensated type of motor is much lower than that of the compensated type. There is no compensating field; therefore, it is necessary to use as strong a main field as possible to keep down the distortion. This of course results in higher reactance voltage and lower power factor, which varies with different designs. There may be cases where the field may be comparatively weak, resulting in very good power factor, and again in cases of very low horse power rating at low speeds, the power factor may be as low as 70 per cent.

The reactance voltage in the armature is small compared with the reactance of the field of the non-compensated motor, and although larger in proportion to the main field in the compensated motor, in neither type has it much effect upon the ultimate result. For commutation reasons, however, it should be kept as low as possible.

In going through the complete design you would, of course, include all of the reactance voltages, even though some of them were negligible.

The air-gap in these motors is about 0.015 in. to 0.020 in. (single air-gap). The very small motors of cheaper design have from 0.020-in. to 0.025-in. and as much as 0.032-in. single air-gap, due to the fact that the appliances using them, in most cases, must be low in price, thus requiring cheap motors. The large air-gap permits of cheaper bearing design and lowers manufactur-costs.

Predetermination of Self-Cooled Oil-Immersed Transformer Temperatures Before Conditions are Constant

BY W. H. COONEY[1]

Associate, A. I. E. E.

Synopsis.—The temperature rises of dynamo electric machines, in changing from one steady thermal state to another, follow an exponential law of the form $1 - \epsilon^{-\beta t}$, where $1/\beta$ is the thermal time constant, or the time required to attain 63.2 per cent of the final change in temperature rise. It is shown here that while the winding temperature rise over room of self-cooled oil-immersed transformers follows this law only after a certain time has elapsed, quite accurate results may be obtained by calculating the time-temperature curves of the top oil temperature rise above room, and the winding temperature rise above top oil separately, since each follows the above exponential law quite closely, then adding them together to get the winding temperature rise above room at any time before conditions are constant. A procedure is explained in detail for calculating β, for either the top oil rise or the winding rise above top oil from the weights of materials the iron and copper losses and the winding and top oil constant temperature rises at any given load. Comparisons of temperatures by test and calculation are presented.

* * * * *

Introduction

While it is of interest to know the length of time necessary for a transformer to attain its final winding temperature rise at rated load, it may sometimes be desirable to know how long an overload may be carried, without exceeding a safe winding temperature, starting at room temperature or at any constant temperature rise less than that due to normal load.

For instance, it is required that railway transformers be tested at a load of 125 per cent or 150 per cent for two hours, starting at the temperature rise due to normal load, without exceeding a winding temperature rise over room of 60 deg. cent. This sort of test does not indicate how long the overload could be carried starting at some other initial steady state, such as room temperature.

To intelligently load the transformer, the operating engineer should have either the results of tests made under the various load conditions or the thermal time constants[2] for the different load and initial conditions for a given transformer. Of course, the most accurate results can be obtained from tests, but it is obvious that this method has its disadvantage in that it is not practical to make tests under all the various conditions under which the transformer might be required to perform. It is, therefore, highly desirable to be able to calculate the time constant, or constants, as the case may be.

In a recent paper[3] a method of calculating the time constant for machines where the parts generating heat (windings and iron of a generator, for example) are not thermally independent and the temperature rise is proportional to the loss, was outlined. It was shown in this paper that the winding temperature rise above room followed an exponential rise with time such that the ratio of temperature rise, at time, t, to final temperature rise $\left(\frac{\theta}{\theta_f}\right)$ could be expressed by $1 - \epsilon^{-\frac{t}{\tau}}$, where τ is a time constant which can be determined graphically from the tested time-temperature rise curve. It was also shown that the value $\left(1 - \frac{\theta}{\theta_f}\right)$ which is equal to $\epsilon^{-\frac{t}{\tau}}$, could be plotted as a straight line against time on semi-log paper.

During the discussion[4] of the previously mentioned paper, it was pointed out that in an oil-immersed self-cooled transformer, the windings are separated from the core by an appreciable amount of insulation and oil, so that the windings may for all practical purposes be considered thermally independent of the rest of the transformer. Although the top oil temperature rise and the winding temperature rise above top oil may each be plotted in terms of $\left(1 - \frac{\theta}{\theta_f}\right)$ as a straight line on semi-log paper, the sum of the two, or winding temperature rise above room becomes a straight line only after the winding temperature rise above top oil has become constant. Moreover, the latter, when continued back as a straight line, does not pass through the origin.

The object of this discussion is to present a method, based on treating the winding temperature rise above top oil and the top oil temperature rise separately, whereby the winding temperature of a transformer can be calculated at any time after a change in load has occurred following a steady state. This method requires a knowledge of the weights of the materials in the transformer, the copper and iron losses, and the constant top oil and winding temperature rises above

1. General Electric Co., Pittsfield, Mass.

2. The reason the value of the constant changes for different loads is because, as shown later, the temperature rise of self-cooled transformers for constant conditions is never proportional to the loss but to the loss raised to some definit power.

3. Kennelly: Thermal Time Constants of Dynamo-Electric Machines, Presented at Midwinter Convention, New York, Feb. 9-13, 1925.

Presented at the Regional Meeting of Dist. No. 1, Swampscott, Mass., May 7-9, 1925.

4. By V. M. Montsinger.

room for some given load such as that required in the acceptance tests.

It is not claimed that this formula is absolutely correct, since the first expression, Eq. No. **3**, in its derivation, as pointed out later, is intended to cover not only winding temperature rise over top oil, but also the top oil temperature rise above room. However, it should be accurate enough for most practical purposes, as an inspection of Figs. 5 to 10 will show.

Final Temperature Rises

In order to calculate temperature rises before conditions are constant, it is, of course, necessary to know the final rise which would be obtained if the load were maintained until conditions become constant. Fortunately, the final rise for any assumed loss of most transformers can be estimated fairly accurately, especially if the rise for some given loss is known.

In the following exposition, the winding temperature rise above room temperature is separated into two parts: top oil temperature rise above room and winding rise above top oil. There are two reasons for this distinction:

In the first place, due to greater thermal capacity, top oil temperature rise, following a change in load, requires approximately as many hours to become constant as the winding rise over oil requires minutes. Secondly, the final values of the two rises do not vary at the same rate with change in load.

It has been found[5] that both the top oil rise of the usual self-cooled transformer and horizontal disk coil rise over top oil vary with loss approximately in accordance with the formula:

$$\theta = k\,P^{0.8} \qquad (\mathbf{1})$$

where θ is the temperature rise, k is a constant in which area of dissipation is one factor, and P is the loss. Temperature rises of vertical coils over top oil vary between the 0.9 and the first power of the loss, and can be expressed close enough for practical purposes by:

$$\theta = k\,P \qquad (\mathbf{2})$$

Formula (**1**) is shown for convenience on log-log paper in Fig. 1. A reference to this figure makes the distinction between top oil rise and coil rise over top oil more readily apparent. Assume that with a ratio of copper loss to core loss of 1:1 the final coil rise over top oil is 10 deg. cent. and the final top oil rise is 30 deg. cent. at some given load. If, due to an increase in load, the copper loss is doubled, the coil rise over top oil according to equation (**1**) for a relative loss of 2 becomes 1.75×10 deg. cent. = 17.5 deg. cent (and according to equation (**2**) becomes 20 deg. cent.) but the relative watts loss for top oil rise, since core loss remains constant, is $(2 + 1)/(1 + 1) = 1.5$ and the rise (Fig. 1) is 1.38×30 deg. cent. = 41.4 deg. cent.

5. Montsinger. Effect of Barometric Pressure on Temperature Rise of Self-Cooled Stationary Induction Apparatus. Proceedings A. I. E. E., Vol. 35, pp. 451-478, April, 1916.

By means of equations (**1**) and (**2**) the final temperature rise for any load can be found provided the rises are known for some definite load and the corrections for change in resistance from one temperature to another are made.

Increase of Temperature Rise with Time

It is a well known fact that temperature rise varies with time according to the exponential curve as shown in Fig. 2. Immediately after the generation of loss in the body under consideration has begun, the temperature rise increases rapidly, since at first it is not sufficient to dissipate any loss, and, consequently, practically all the loss is stored. As the rise increases, the dissipation to the surrounding medium (oil or air, as the case may be) increases, until finally heat storage has been completed and all the generated loss is dissipated.

If the initial generated loss is W before the temperature rise has begun, the generated loss at time t and temperature rise θ for a constant current can be expressed as $W\,(1 + \alpha\,\theta)$ where α is the resistance coefficient of copper. The loss stored at time t is $C\,\frac{d\,\theta}{d\,t}$, where C is the thermal capacity of the body being heated. The loss dissipated can be expressed approximately by $K\,\theta$. (Multiplying the initial loss by a resistance correction is not strictly correct when using the formula for oil temperature rise, since core loss may even decrease slightly with temperature. But $\alpha\,\theta$ is usually of the order of 15 or 20 per cent and copper loss, especially for overloads, is several times as large as the core loss, so that no great error is caused. If α were multiplied by the ratio of copper loss to total loss, it would result not only in a complicated equation, but also the necessity of a separate one, for oil top temperature rise).

Equating the loss generated to the loss stored and dissipated at time t and temperature rise θ the equation obtained is

$$W\,(1 + \alpha\,\theta) = C\,\frac{d\,\theta}{d\,t} + K\,\theta \qquad (\mathbf{3})$$

The integration of this equation, shown in the Appendix, gives the formula:

$$\theta = \theta_f\,(1 - \epsilon^{-\beta t}) \qquad (\mathbf{4})$$

where θ_f is the final temperature rise caused by the loss whose initial value is W, ϵ is the base of Naperian logarithms and

$$\beta = \frac{W}{C\,\theta_f} \qquad (\mathbf{5})$$

This constant may be more familiar in its reciprocal form, where it is known as the exponential thermal time constant, or the time necessary to attain 63.2 per cent of final rise:

$$\tau_\epsilon = \frac{1}{\beta} = \frac{C\,\theta_f}{W},$$

or as the binary time constant[3]:

$$\tau_2 = 0.69315\,\frac{C\,\theta_f}{W}$$

If t is expressed in minutes and W in watts, for winding rise over top oil

$$C = 2.96\,\frac{A + a}{2\,a} \times \text{lb. of bare copper} \qquad (6)$$

where A and a are the insulated and bare cross-sections of conductor in the windings, respectively.

For top oil temperature rise over room, when t is expressed in hours and W in watts,

$$C = \frac{3.5\,(\text{lb. Copper} + \text{lb. Core} + \tfrac{2}{3}\,\text{lb. Tank}) + 90\,(\text{Gallons of Oil})}{60} \qquad (7)$$

Since the calculation of C is of great importance in this method, it may be of interest to show the reasons for the above values of the constants.

In c. g. s. units, the following values of specific heat are assumed constant for all temperatures, although there actually is a small variation, which may be neglected for the ranges of temperature considered.

Specific Heat Copper = 0.0935
Specific Heat Iron = 0.115
Specific Heat Oil = 0.47

The thermal capacity may be expressed in more practical units:

Copper = 2.96 Watt minutes per pound per deg. cent.
Iron = 3.6 Watt minutes per pound per deg. cent.
Oil = 105 Watt minutes per U. S. gallon per deg. cent.

It is apparent that all the oil in a transformer is not heated to the same temperature as the top oil for the reason that the temperature at the bottom of the tank is cooler than at the top. The ratio of mean to maximum temperature in the gradients of self cooled tanks ranges from about 75 per cent to 95 per cent, depending on the design. Assuming an average of these figures, or about 86 per cent as a representative figure, the constant for oil then becomes 0.86 × 105, or 90, as shown in formula (**7**).

A similar line of reasoning applies to the tank. The base of the tank, the bottom end of the wall, and, unless there is an oil conservator, the cover dissipate very little or no heat. For this reason, ⅔ of the tank weight is taken. Since the ratio of iron to copper in a transformer is about 5 or 6 to 1, the metal may be lumped together and multiplied by the factor of 3.5 instead of 2.96 and 3.6 for copper and iron respectively.

In considering the windings of a transformer, if the insulated cross-section of the wire is appreciably larger than the bare cross-section it should be taken into account. Fibrous insulation is usually so impregnated with insulating compounds or oil that its thermal capacity is practically that of the latter. Although oil has five times the thermal capacity of copper by weight, copper has about ten times the density of oil, so that the insulation may be considered to have ½ the thermal capacity of copper by volume as indicated in eq. (**6**).

When the weights of materials are not known, the values of C may be found by observing the time-temperature rise curves for both the top oil and the winding rise over oil when the transformer heats up, preferably starting at room temperature and 100 per cent load and excitation. The values of W and θ_f should be determined. β may be found by a graphical method[3], and C solved for in equation (**5**). This value of C will be constant regardless of the loads applied or the initial conditions.

Application of the Formula

In changing from one steady state to another, the problems encountered may be grouped into three classes:

a. The application of excitation and load to a transformer which is at room temperature.

b. Application of load after a constant oil rise over room temperature has been attained due to core loss.

c. Application of an increase in load after a constant rise of windings and oil has been attained due to a smaller load and core loss.

Since the application of a formula becomes simpler, both in explanation and in use, when examples of it are shown, the following problems are worked out under each of the classifications just specified. The relative values of the characteristics given below are typical of a moderate sized power transformer.

Assume a transformer with the following characteristics:

At 100 per cent load and excitation:
40 deg. cent. top oil temperature rise.
15 deg. cent. winding temperature rise over top oil.
Copper loss, 9000 watts.
Core loss, 6000 watts.

Weights:
900 gallons of oil.
1000 lb. copper.
4200 lb. core iron.
4500 lb. tank.

(Neglect resistance corrections for simplicity.)

(a) 125 per cent load and excitation starting cold.

θ_f: For top oil rise, relative watts $= \dfrac{20080}{15000}$ $= 1.338$; from Fig. 1, oil rise $= 1.26 \times$ 40 deg. $= 50.4$ deg. cent.

For coil rise over top oil, assume that the construction is such that formula (**2**) applies. Coil rise over oil $= 1.563 \times$ 15 deg. $= 23.5$ deg. cent.

C: For oil rise

$$= \frac{3.5(1000 + 4200 + 3000) + 90 \times 900}{60}$$

$= 1830$

For coil rise over oil $= 2.96 \times 1000 = 2960$,
(Neglecting insulation.)

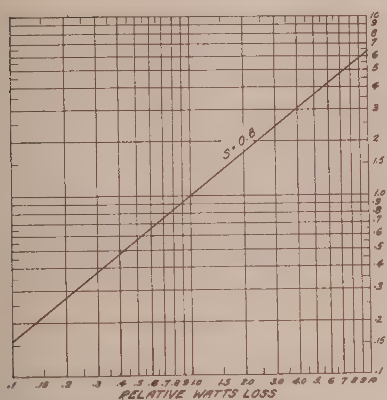

FIG. 1—REPRESENTATION OF $\theta = k\,P^{.8}$ (FORMULA 1) IN TERMS OF RELATIVE TEMPERATURE RISE AND RELATIVE WATTS

W: For top oil rise = 20,080 watts.
For coil rise over top oil = 14,080 watts.

$$\beta: \text{ For oil rise } = \frac{20{,}080}{1830 \times 50.4} = 0.217$$

$$\text{For coil rise over oil } = \frac{14{,}080}{2960 \times 23.5}$$

$= 0.202$

When these values of β are multiplied by t in hours and minutes respectively, the corresponding values of

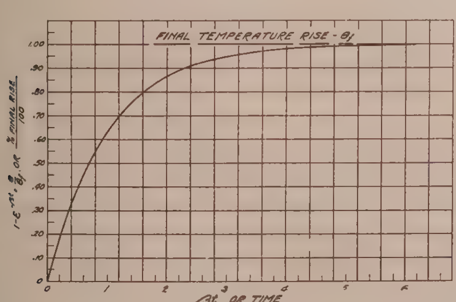

FIG. 2—VARIATION OF $1 - \epsilon^{-\beta t}$, WITH βt, OR INCREASE OF TEMPERATURE IN PER CENT OF FINAL RISE WITH TIME

$1 - \epsilon^{-\beta t}$ may be found from Fig. 2. The latter when substituted in formula (4) determines the value of θ at time t. The results are plotted in Figs. 3 and 4.

(b) Constant oil rise due to excitation, followed by 100 per cent load.

θ_f: For oil rise

Due to excitation, relative watts = 0.4, rise = 19.2 deg. cent.

Due to excitation and 100 per cent load, oil rise = 40.0 deg. cent.

Rise due to copper loss = 20.8 deg. cent.

For coil rise over oil at 100 per cent load = 15 deg. cent.

C: Same as in (a).

W: For oil rise = 9000 watts.
For coil rise over oil = 9000 watts.

$$\beta: \text{ For oil rise } = \frac{9000}{1830 \times 20.8} = 0.236$$

$$\text{For coil rise over oil } = \frac{9000}{2960 \times 15} = 0.202$$

The variation of θ, with time, following the same procedure as in (a), is plotted in Figs. 3 and 4.

(c) 125 per cent load following (b).

θ_f: For oil rise = 50.4 deg. − 40 deg. = 10.4 deg. cent.

For coil rise over oil = 23.5 deg. − 15 deg. = 8.5 deg. cent.

C: Same as in (a).

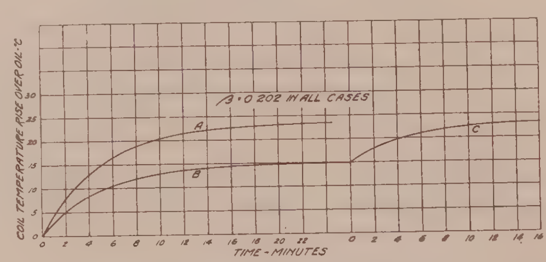

FIG. 3—WINDING TEMPERATURE RISE OVER TOP OIL, CALCULATED FOR THE TRANSFORMER OF ASSUMED CONSTANTS UNDER THE FOLLOWING CONDITIONS:

(A) 125 per cent load and excitation, starting at room temperature.
(B) 100 per cent load and excitation, starting at oil temperature rise due to core loss alone.
(C) 125 per cent load applied after conditions are constant for (B).
Calculations of β are shown in the text.
Note: 0 time for (C) corresponds to 18 hours in Fig. 4.

W: For oil rise = 20,080 − 15,000 = 5080 watts
For coil rise over oil = 14,080 − 9000 = 5080 watts

$$\beta: \text{ For oil rise } = \frac{5080}{1830 \times 10.4} = 0.267$$

$$\text{For coil rise over oil } = \frac{5080}{2960 \times 8.5} = 0.202$$

The results obtained from these values of β and θ_f are also plotted in Figs. 3 and 4.

Although corrections for resistance have been purposely omitted in the foregoing, the distinction should be made that θ_f is calculated for the loss at the final temperature whereas the W used in β is the loss at the initial temperature before the change.

It will be noted that in all three cases the value of β

for coil rise over top oil remains the same. This is due to the fact that θ_f is taken as proportional to W, which would not be the case if resistance corrections were considered or if a winding were assumed whose construction caused it to follow formula (1).

Comparison of Tested and Calculated Rises

A comparison of tested coil temperature rise over top oil and that calculated by formula (4) is shown in Fig. 5.

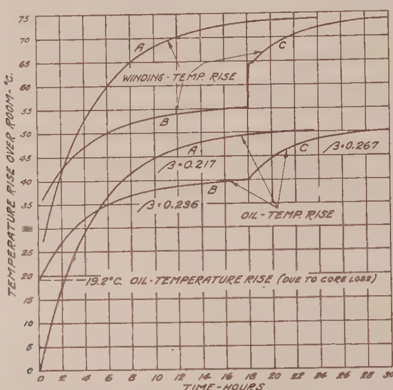

Fig. 4—Oil and Winding Temperature Rises Above Room Calculated for the Transformer of Assumed Constants Under the Following Conditions:

(A) 125 per cent load and excitation, starting at room temperature.
(B) 100 per cent load and excitation, starting at oil temperature rise due to core loss alone.
(C) 125 per cent load applied after conditions are constant for (B).
Winding temperature rises above room are obtained by adding the winding rises over oil (Fig. 3) to the oil rises. Calculations of β for the oil rises are shown in the text.

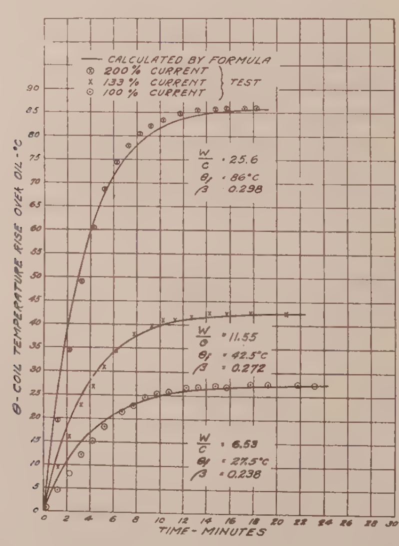

Fig. 5—Variation of Coil Temperature Rise Over Oil, with Time, for Various Currents, as Observed by Thermocouple on Disc Coils in Horizontal Position

Insulated thermocouples were inserted in a horizontal disk coil stack, and various currents, in excess of normal to get higher readings to minimize any absolute errors, were put through the windings. A thermocouple was selected which was representative of the coil rise over oil by resistance. Readings were taken at intervals during the time required to attain final rise over oil. The calculated values are somewhat higher at first than test, but this may be due to the insulation, between the copper and the thermocouple, causing a temperature lag in the readings. The calculated values of β are shown in the figure.

An important point to be noted in connection with Fig. 5 is that, since θ_f does not increase as fast as W for this type of winding, β increases for the higher values of current. An inspection of the test values shows a confirmation of this method of calculating β, for the greater the current, the quicker is a given percentage of final rise attained.

To determine how closely tests would agree with the type of calculation shown in (c) of Fig. 4 for oil temperature rise, a 75-kv-a. transformer was given 100 per cent load and excitation starting at room temperature. Hourly readings were taken to determine the variation of top oil temperature rise over room with time until the readings were practically constant. Then 125 per cent load was applied, and the readings continued until conditions were again practically constant. The readings and calculation of β, and the factors on which it is based are shown in Fig. 6. The observations made in connection with Fig. 5 apply here also. θ_f has not increased as rapidly as W (see formula 1) and consequently β has increased about 50 per cent in the overload. The general conclusion is that when the ratio of W to θ_f is not constant in all cases, β should be calculated for the particular load and initial condition under consideration.

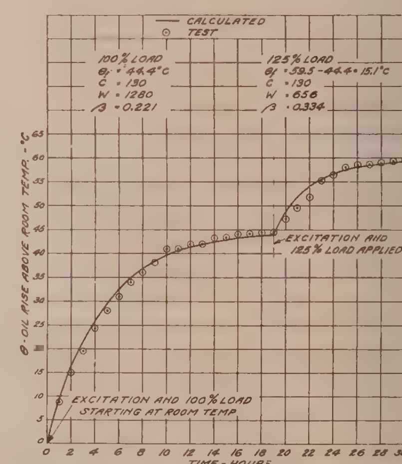

Fig. 6—Variation of Top Oil Temperature Rise, with Time, in a 75-kv-a. Transformer. 100 Per Cent Load and Excitation Applied at Room Temperature Until Rise is Constant, Followed by 125 Per Cent Load Until Conditions are Again Constant. (Similar to (C) in Fig. 4)

For the purpose of checking up the form of calculation

shown in (b) of Fig. 4 for oil temperature rise, a 100-kv-a. transformer was put under excitation until the top oil temperature rise caused by the core loss was constant. Then normal load was applied and the top oil temperature rise observed hourly until practically final

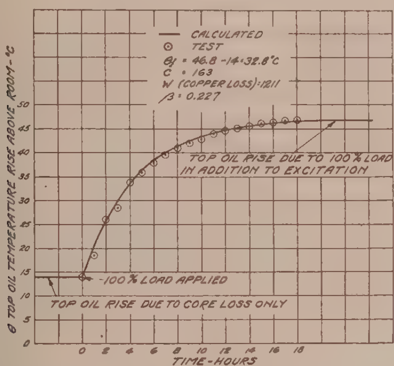

Fig. 7—Variation of Top Oil Temperature Rise, with Time, in a 100 Kv-a. Transformer. Normal Load Applied after Constant Top Oil Temperature Rise, Due to Core Loss Only, has been Attained. (Similar to (B) in Fig. 4)

rise was attained. The observations obtained, and the calculation of β, are presented in Fig. 7. Hourly readings were also taken as the top oil was heating up due to core loss. They check up very closely with the calculated values, but since they are of minor importance they are omitted.

The 100-kv-a. transformer, whose performance is shown in Fig. 7, was also tested starting at room tem-

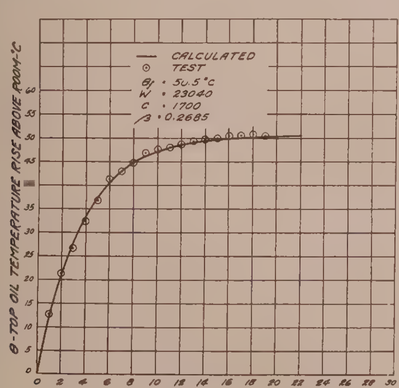

Fig. 8—Variation of Top Oil Temperature Rise, wtih Time, in a 2000-Kv-a. Transformer. Normal Load and Excitation Applied Starting at Room Temperature. (Similar to (A) in Fig. 4)

perature, with a good agreement of tested and calculated values, but due to the similarity of the test to the one starting with core loss temperature, it is not reproduced. Figs. 6, 8, 9, 10 show how well the formula checks tests starting at room temperature, regardless of the size of transformer, for 75, 2000, 5000 and 12,500 kv-a., respectively. These observations of top oil temperature were all taken hourly as the transformers were heating up, starting at room temperature, after 100 per cent load and excitation had been applied, conditions similar to those of (a) in Fig. 4. The calculated values of β are given in the respective figures in addition to the test data.

A general inspection of Figs. 5 to 10 shows that the calculated curve does not reach a maximum and flatten out quite as quickly as the test results. This is due to the fact that theoretically the exponential curve does

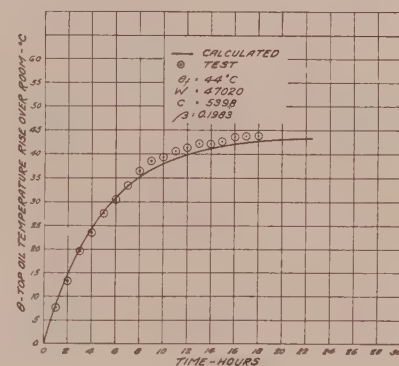

Fig. 9—Variation of Top Oil Temperature Rise, with Time, in a 5000-Kv-a. Transformer. Normal Load and Excitation Applied Starting at Room Temperature. (Similar to (A) in Fig. 4)

not become constant until infinity. After a certain per cent rise has been attained, extending the calculation several hours, in considering oil rise, may result in the addition of only one or two tenths of a degree. This is obviously absurd. Since commercial thermometers and thermocouples are seldom more accurate

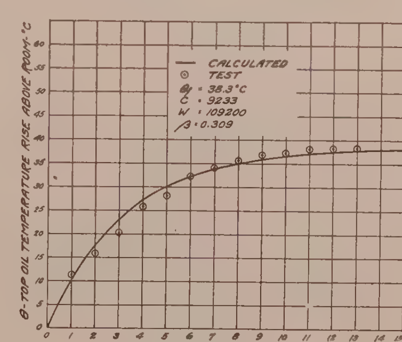

Fig. 10—Variation of Top Oil Temperature Rise, with Time, in a 12,500-Kv-a. Transformer. Normal Load and Excitation Applied Starting at Room Temperature. (Similar to (A) in Fig. 4)

than $\pm$ 0.5 deg. cent., calculations may be shortened by carrying them only up to within 0.5 deg. cent. of final rise.

Restrictions in the Use of the Formula

While the proposed method should apply to the majority of self-cooled transformers, it would be mis-

leading not to indicate some of the factors which may affect its applicability.

Considering first the question of coil rise over oil, it is apparent that the windings should be practically thermally independent of any surrounding medium except the oil, which carries away heat from the windings chiefly by convection. If, for instance, the coils are wound directly on the core, as in the case of many small transformers, there is a flow of heat into the core by conduction in addition to that given to the oil. The result is a very complicated thermal condition as far as calculation is concerned. Naturally, such a winding will not rise in temperature as fast as the proposed formula would indicate for a similar winding separated from the core by an insulating cylinder, for example, since, in such a case, the formula would indicate too high a rise. Tests would be necessary to show the true heating curve in order to get the safe maximum performance for any given design. It might be possible, by adding a portion of the core's thermal capacity to that of the copper, to get a good approximation but the amount added would be empirical, consequently it is impossible to give any general rule that would apply to all cases.

Before applying the formula to top oil temperature rise, it might be well to consider whether the transformer under consideration corresponds to the assumptions on which C in formula (7) is based. For instance, in small transformers of low voltage where it is not necessary to have large voltage striking distances the metal factor (weights of metal multiplied by 3.5) may be as large or larger than the oil factor ($90 \times$ gallons of oil). In that case, it may be advisable to give more attention to the former. The copper and iron may be multiplied by their respective factors of 2.96 and 3.6, more than ⅔ of the tank may be used, and the other metal in the transformer such as the core clamps, if appreciable, should be added in. Moreover, a core which runs at high density and consequently high mean temperature rise may have its weight multiplied by the ratio of mean core temperature rise above room to top oil temperature rise. If these factors are not taken into account the test points may be somewhat lower at first than the calculated These additions should not be made unless it is desired to get maximum performance from the transformer. In any event, they should be made cautiously, for the formula as it stands will be only a little conservative for the cases mentioned above.

About the only factor which could possibly cause the tested top oil temperature rise to exceed the calculated would be a ratio of mean to top oil temperature rise of less than the 86 per cent used for the determination of C in Formula (7). This could conceivably happen through the use of a type of winding cooled in such a way, or so located, that all its heat is delivered to the oil near the top of the tank. Any doubts as to this point can be easily and quickly settled by placing thermometers in a vertical line from top to bottom of the outside of the tank in question and determining the ratio of the mean to the maximum temperatures read when the top oil temperature rise is near its normal value. If this ratio is less than 86 per cent, the factor of 90 should be decreased in like proportion.

Temperature Limits

Although the purpose of this paper is only to indicate a method of calculating temperature rises, it may not be amiss to indicate the temperature limits which should not be exceeded. According to the A. I. E. E. Rules, a maximum rated transformer should not exceed a 55 deg. cent. winding temperature rise by resistance over a 40 deg. cent. room at normal load. For railway transformers, a 2-hour overload resulting in a 60 deg. cent. rise is permitted. Therefore, this method of calculation should be used to show the length of time for which load may be maintained before the calculated winding temperature rise above room plus the room temperature, assumed for the transformer under consideration, exceeds a temperature of 95 deg. cent., by resistance, for maximum rated transformers, or 100 deg. cent. for railway transformers.

Acknowledgment

The author wishes to acknowledge the criticisms and suggestions of Mr. V. M. Montsinger, which have been of great assistance in the preparation of this paper. In fact, the development of this particular method of applying the exponential law to the heating of transformers during a transient state was made by Mr. Montsinger several years ago, but it was never published. Experience has shown this method to be accurate enough for all practical purposes.

Appendix

Derivation of Formula (4)

$$W\,(1 + \alpha\,\theta = C\,\frac{d\,\theta}{d\,t} + K\,\theta$$

$$C\,\frac{d\,\theta}{d\,t} + \theta\,(K - \alpha\,W) = W$$

$$C\,\frac{d\,\theta}{d\,t} + C'\,\theta = W, \text{ where } C' = K - \alpha\,W$$

$$\frac{d\,\theta}{d\,t} = \frac{C'}{C}\left(\frac{W}{C'} - \theta\right)$$

$$\int \frac{d\,\theta}{\theta - \dfrac{W}{C'}} = -\frac{C'}{C}\int d\,t$$

$$\log\left(\theta - \frac{W}{C'}\right) = -\frac{C'}{C}\,t + \log C''$$

$$\theta - \frac{W}{C'} = C''\,\epsilon^{-\frac{C'}{C}t}$$

$$\theta = \frac{W}{C'} + C'' \epsilon^{-\frac{C'}{C}t}$$

When $t = 0$, $\theta = 0$, and

$$-\frac{W}{C'} = C''$$

Then $\theta = \frac{W}{C'} (1 - \epsilon^{-\frac{C'}{C}t})$

Substituting for C',

$$\theta = \frac{W}{K - \alpha W} (1 - \epsilon^{-\frac{K - \alpha W}{C}t})$$

When $t = \infty$, $\theta = \frac{W}{K - \alpha W} = \theta_f$

Letting $\beta = \frac{K - \alpha W}{C} = \frac{W}{C \; \theta_f}$,

$$\theta = \theta_f (1 - \epsilon^{-\beta t})$$

Transformer Tap Changing Under Load

BY H. C. ALBRECHT[1]

Associate, A. I. E. E.

Synopsis.—*Attention is called to the need for voltage and power-factor regulating equipment on lines used for tying together large generating stations and for interconnection of systems. Such lines must be capable not only of transferring large amounts of energy in either direction, but must also be suitable for connecting generating sources operating at essentially equal voltages.*

The important characteristics of the three principal methods for voltage regulation on interconnecting lines,—namely, synchronous condensers, tap changing under load, and induction regulators,—are presented, discussed and compared. The comparison includes such factors as first cost (including installation) reliability, ease of operation, losses, effect on system power factor and losses, maintenance, adaptability to reversible energy transfer and ability to give close voltage regulation.

The requirements of regulating equipment, particularly from the operator's standpoint, are discussed with the idea of bringing out the necessity of obtaining a high degree of reliability, ease of operation and flexibility to meet the various operating conditions.

The fields of application of various methods of regulation are discussed, showing the advantages of each for different requirements and pointing out that in some cases the best solution of the problem lies in the application of a combination of two different methods of regulation to secure the best overall results.

Brief descriptions of three installations (two of tap changing under load, and one of induction regulators) for voltage regulation and power factor control on lines of The Philadelphia Electric Company are included.

* * * * *

IN an effort to obtain satisfactory voltage regulation more economically for certain transmission requirements involving step-up transformation during the past two or three years methods and equipment have been developed by which the voltage ratio of large power transformers can be changed while in service without interrupting the load. Changing taps by any such method is commonly referred to as "Tap Changing under Load."

The purpose of this paper is to indicate, so far as possible, the field in which transformers provided with tap-changing equipment might be economically and satisfactorily applied, comparing their characteristics, advantages and disadvantages with those of the other better known types of regulating equipment, such as synchronous condensers and induction regulators. The development of equipment for tap changing and the various schemes by which this may be accomplished will be but briefly referred to, as this is to be the subject of other papers. As a result of experience in a recent installation of four 20,000-kv-a., 66-kv. transformers of this type on tie lines between two important generating stations of The Philadelphia Electric Company system, however, some suggestions will be made from the standpoint of the operating company relating to their design, construction and installation.

Where step-up transformation is involved, voltage regulation requirements have usually been those relating to one way transmission, but the tremendous growth in capacity of individual systems in the last decade, and the decided trend toward interconnection of systems, has brought with it another somewhat different problem of controlling voltage and transferring reactive kilovolt-amperes with reversible energy flow. The time is not long past when there were scarcely any ties between neighboring systems and but few of any considerable capacity between generating stations of the same system, since most companies could boast of but one large plant. The greatly increased demand for energy has resulted in the building of many large capacity generating stations, which, for economic operation, are tied together in any one system. In the past few years considerable progress has been made in the interconnection of adjacent systems to secure even greater economies. With the general spread of the "superpower" idea through the country and the consequent increase in the number of such ties, this newer problem of regulation, where energy transfer may

1. Engineer, Station Elec. Design & Const. Philadelphia Electric Co.

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be in either direction, is of growing importance.

Except for the induction regulator which has been applied only to a limited extent, until the recent development of tap-changing equipment, the synchronous condenser has been practically the only means of obtaining the voltage regulation to meet the requirements discussed in this paper. With tap-changing equipment available, however, the best solution of many problems may be a combination of this equipment with synchronous condensers, or, in certain cases, of tap-changing equipment alone where its range is sufficient. Of course, there are many cases in which bulk power is supplied to distant points, where it is practicable to obtain some or all of the required regulation by variation of voltage at the generating station, particularly when there is no local distribution from that point.

Application of the three above mentioned types of equipment, for obtaining voltage regulation where step-up transformation is involved, may be commented on as follows:

Synchronous Condensers

This type of equipment has been extensively used for voltage regulation, particularly for one-way transmission, and has the following characteristics:

a. Very important advantage of ability to carry reactive kilovolt-amperes, thus minimizing system osses and permitting best utilization of system capacity.

b. Ability to obtain smooth voltage regulation and, when necessary in cases where the charging kilovolt-amperes of the line is high, to prevent voltage rise at light loads.

c. Ability to maintain level voltage transmission which may be of advantage where loads are tapped off along the line.

d. High cost of complete condenser installation, due not only to cost of the apparatus in the capacities required but also to the necessity of providing foundations and building.

e. Comparatively high operating and maintenance costs and losses; the latter, however, generally being more than balanced by savings in system losses.

f. Extremely high cost of installations to take care of reversible energy transfer, as duplicate equipment must be installed at each end of the line with possibly little appreciable additional saving in system capacity or losses to offset charges on the additional investment.

g. Units may be taken out of service purposely or accidentally without necessarily causing a serious disturbance.

Tap-Changing Transformers

This type of equipment of recent development, so far installed chiefly on tie lines between generating stations, is possessed of the following characteristics:

a. Very low cost, since the only amount involved is practically the difference between transformers provided with tap-changing equipment and those not so provided.

b. Adaptability to reversible energy transfer where line power factor is high or distances are relatively short.

c. Inability to improve system power factor and thus decrease losses and increase system capacity.

d. Inability to give smooth voltage regulation, changes being made in steps.

Induction Regulators

Induction regulators have been used, to a limited extent, on the low-tension side of transformers connected with high-voltage transmission lines and have the following characteristics:

a. Moderate cost.

b. Adaptability to reversible energy transfer.

c. Ability to give smooth voltage regulation.

d. Inability to improve system power factor and thus decrease losses and increase system capacity.

e. Moderate losses.

f. Introduction of phase angle between line and bus voltage by polyphase regulators.

Comparisons

In considering these three types of regulating equipment, it will be seen that induction regulators and tap changers perform very much the same function—they vary the voltage, but have no beneficial affect on power factor, as in the case of synchronous condensers. Of these two equipments, tap changing is considerably cheaper, more efficient and occupies less space. For instance, a 7½ per cent buck-and-boost, polyphase, induction regulator, in series with the low-tension side of a 20,000-kv-a., 66-kv., three-phase transformer, would probably cost almost as much as the transformer itself, while a transformer of the same capacity provided with tap-changing equipment to give the same voltage range, would probably cost less than 150 per cent of the transformer without such equipment. In addition to this advantage in first cost, there would be a considerable annual saving by elimination of the regulator losses. There is also another advantage in favor of the tap-changing equipment; the regulator is almost as large as the transformer itself, requiring special foundations and more space than the tap-changer equipment. The regulator does give a smooth variation of voltage instead of in steps, but in many cases this is not of sufficient importance to overcome the other disadvantages. An application of tap-changing transformers of considerable interest is one in which the voltage change from one tap to the next is accomplished gradually through the use of a small induction regulator which may require an insulating transformer between it and the main transformer.

The polyphase regulator also introduces a phase angle between line voltage and bus voltage, which makes paralleling difficult. When voltage regulation is desired for existing installations, it may be quite difficult and expensive to safely apply tap changing and, in such cases, the induction regulator may work out very

satisfactorily. It, therefore, seems that in new installations where step-up transformers are required, tap-changing equipment has decided advantages over regulators.

In a comparison of tap-changing equipment with synchronous condensers for voltage regulation, the two points of outstanding importance are, on one hand, the tremendous advantage of first cost of the tap-changing equipment over the condenser installation, and on the other hand, the ability of the condenser to supply reactive kv-a. in addition to voltage regulation, thus minimizing system losses and permitting best utilization of system capacity. It would seem, however, from an economic standpoint that, in many cases, the advantages of tap-changing equipment would outweigh those of condensers, if the tap changers would give the desired voltage range. As this is perhaps hardly possible, the best solution of many problems would very likely be a combination of tap-changing equipment with a smaller capacity of condensers than would otherwise be required. This compromise would permit of installation of condenser capacity sufficient to bring the power factor to the economical point and obtain the remaining regulation required with tap changing. Where the system power factor is already fairly high, the desired voltage regulation can be obtained with tap-changing transformers of the maximum, practical voltage range, supplemented by condenser equipment if necessary. The combination of condensers and tap-changing transformers gives the advantages of both types of equipment and overcomes most of the disadvantages.

In many cases where the charging kv-a. of the line at no load is high, there may be no alternative other than the installation of condensers; but, even with this the case, the combination may work to advantage. It is again pointed out that where it is practical to vary the generating station voltage considerably, this, in combination with the use of condensers, may be a better solution than tap changing.

Development of Tap Changing

There has been a growing appreciation of the advantages of taps in transformer windings and a desire to increase their availability, and this even with recognition of the fact that taps do introduce some slight hazard and that the number should be kept down to the minimum advantageous for use. This first took the form of adding a terminal board with links whereby the ratio of transformation could be varied. However, this required the opening of a handhole over the terminal board or the lifting of the cover—an inconvenient procedure at any time and especially undesirable in bad weather. Thus, with the necessity for changing taps frequently to care for seasonal variations in load, this led to the development of ratio adjusters operated from without the transformer tank, with the unit out of service. As the necessity for making these changes became daily rather than seasonal, the next step was naturally towards means of changing taps without interrupting the load.

It may be of interest here to recall that many years ago schemes were developed and applications of small capacity were made in which taps were brought out from transformers to a dial-head and line connections were changed from one tap to another while the section of winding between taps was momentarily short-circuited through reactance.

There are several methods whereby tap changing under load may be accomplished; among them the use of (*a*) two parallel windings which can be cut out of circuit, one at a time, by oil circuit breakers or contactors in order to change taps; (*b*) one winding in which adjoining taps are momentarily tied together through oil circuit breakers or contactors during the change-over with or without "bridging" reactance or small induction regulator; (*c*) one winding in which taps are changed by taking each phase out of service in succession, the load being carried open-delta on the two remaining phases in the meantime.

In cases *a* and *b*, the windings from which the taps are brought out may be either those of the main transformer themselves or those of an auxiliary regulating transformer excited from the main bank. While the former is more compact and cheaper both in first cost and operating losses, it does not provide a means for keeping all the tap-changing equipment outside the main tank. Where regulation is desired on an existing transformer bank, this may be accomplished by the addition of such an auxiliary regulating transformer.

Where the voltage of the circuit is too high to permit the safe installation of tap-changing devices directly, it is possible to accomplish tap changing through insulating transformers, although, of course, this would be at increased cost.

The application of the general principle of tap changing under load presents possibilities for many ingenious arrangements to meet specific requirements, illustrated by the variety in the equipments already in service or on order. Undoubtedly there will be further developments involving new schemes or modification of existing ones.

While this paper treats mainly of tap changing applied to step-up or step-down transformers, it should be pointed out that tap changing can also be applied to series transformers where the line to be regulated includes no voltage transformation.

Philadelphia Electric Installations

It will be of interest to briefly describe an 80,000-kv-a. installation of tap-changing transformers at the Chester Generating Station of The Philadelphia Electric System. This station is fourteen miles from the Schuylkill Generating Station and is connected by two 66-kv. overhead circuits of No. 00 copper. Until recently two 18,750-kv-a. banks were installed at each end of the lines. Although these lines were intended to

be for generating station ties only, it was not very long before two important, large customers for special reasons were tapped off not far from the center of the lines. Control of transfer of load and reactive kv-a. for the first two years was obtained by variation of the bus voltage of the Chester generating station, as the local distribution was not extensive and not particularly affected thereby. However, in 1920, this became less practicable and the need for some means of more effectively controlling the lines under various loading conditions was so great that after much consideration two 1750-kv-a., 13,600-volt induction regulators, to give 9 per cent buck-and-boost in a 18,750-kv-a. circuit, were purchased and installed at the Schuylkill end of the lines. These were and probably still are the largest regulators ever built. In 1924, however, it was decided to double the transformer capacity installed at the Chester Station end and extend a 66-kv. tap from the line to a distribution substation with requirement of 20,000 kv-a., the transformers from Chester being transferred to that point. The increased line loading brought a greater voltage drop and it was deemed best to take care of this by making the new transformers at Chester tap changing instead of purchasing additional induction regulators or installing synchronous condensers. Five per cent buck-and-boost induction regulators were purchased for the tap off substation, as tap changers could be applied to the transformers available only with difficulty. Four 20,000-kv-a., 13.8/69-kv., delta-delta, three-phase, water-cooled transformers were placed in service the first of last November and arranged with six taps in the low-tension winding, to give up to 13 per cent rise at no load in the high-tension winding, or 78,000 volts. The low-tension windings are in two parallel circuits with taps in the middle of each winding, taps being changed on one winding, while the other is temporarily carrying the entire load. A single operation of a control switch carries to completion, the changing from one tap to another, in all three phases. Other papers give description of this equipment and its design problems in detail.

Since their installation these transformers have been operating very satisfactorily. Their control is simple and tap changes of 2.2 per cent cause no noticeable disturbances on the line. While the tap changers at Chester and the regulators at Schuylkill are non-automatic and under the control of the operators, the regulators at the substation are controlled from a contact-making voltmeter, thus insuring the maintenance of a constant voltage at that point irrespective of variations of the voltage of the 66-kv. line, due to direction and amount of energy transferred.

Construction work is well under way on the Richmond Station in Philadelphia, designed to ultimately house twelve turbo-generator units of at least 50,000-kw. capacity each, the first two of which are expected to be in operation by the end of 1925. It is anticipated that about one-half of the minimum ultimate capacity of 600,000 kw. will be distributed at 13.2 kv. and the remainder at 66 kv., and that half of the twelve generators will be connected to the 13.2 buses and the others to the 66-kv. buses through transformers connected directly to the generator leads. Provision is being made to tie the 13.2 and 66-kv. buses together through three 60,000-kv-a. transformer banks. As distribution within the next few years will be considerably greater at 13.2 kv. than at 66 kv., the first few generators will be connected to the 13.2-kv. buses. Two of the three 60,000-kv-a. tie transformer banks, each consisting of three 20,000-kv-a., single-phase, water-cooled units, connected delta-Y, have been ordered and will be placed in service the latter part of this year to provide for the demands for 66-kv. supply. In order to facilitate the ultimate reversible transfer of energy between the 13.2 and 66-kv. buses, these transformers have been ordered with tap-changing equipment of 10 per cent range in four 2½ per cent steps. An interesting feature of this installation will be that individual tap-changing equipments will be furnished with each single-phase transformer, no provision being made to have the taps on the three different phases changed simultaneously.

General Comments

In general, transformers, particularly in large capacities, have a record of high reliability. Tap changing necessarily adds complications to both the transformer itself, and the auxiliary equipment. It is extremely important that the design be developed in all its details so as to minimize any adverse affect upon the overall reliability of the equipment. Operators are reluctant to add complications to important equipment, but in large capacity units, in which tap changing is of particular advantage, the extra expense to secure exceedingly substantial tap-changing equipment is a very small percentage of the total cost. A requirement of The Philadelphia Electric Company is that the tap-changing equipment inside the transformer tank be built so substantially as to require no attention under the expected duty other than that which would naturally be given on the rare occasions when it is necessary to untank the unit in case of winding failure.

It is true that some hazard is introduced by tap-changing equipment and some operators prefer schemes in which taps are brought outside the tank because of possibility of trouble in the tap-changing mechanism. This, however, brings about other disadvantages, such as the hazard in the additional exposure of important circuits and added first cost. Transformer windings are quite often somewhat special when built for tap-changing service and the design must be carefully worked out to obtain the best balance to meet all requirements; for instance, with schemes involving parallel windings, care must be taken to obtain the best compromise between circulating current and regulation when the load is carried for a short time on one winding during tap changing on the other.

The amount of tap changing range that is practicable and the affect upon cost and characteristics are interesting subjects for discussion and have important bearing upon its application, particularly for reversible energy transfer. For instance, as previously indicated, the economic solution of many problems may involve a combination of synchronous condensers with tap-changing transformers in proportions determined largely by the maximum practicable range of the tap-changing equipment. It must be appreciated, however, that high ranges impress voltages higher than normal upon transformer, oil circuit breaker and other equipment, and the line itself.

It is of the highest importance that the design and construction of the tap-changing mechanism be such as to insure sturdiness and reliability; and there should be no tendency to skimp in this direction. Whether oil switches or contactors should be used for disconnecting devices, and the relative merits of different types of ratio adjusters, are matters to be carefully looked into for particular applications. Tap-changing equipment is well adapted to remote control and experience has indicated the value of but one operation of a control switch for a complete movement from one tap to another. Of course provision must be made for manual operation in case of motor trouble, or failure of control system. The complete movement, whether remotely or manually operated, should be made in the minimum length of time possible without any shock to the mechanism or sacrifice in durability. That portion of the tap-changing mechanism external to the transformer should be properly housed and specially designed to withstand moisture from condensation. The mechanism should be readily accessible for inspection and maintenance.

It is essential that the operator know the tap on which the bank is operating and that any change he desires has actually been completed. Therefore, a position indicator of some kind should be provided on the switchboard and also at the mechanism. It is often desirable to know the voltage on the high-tension side of transformer banks and costly high voltage potential transformers may be avoided if the voltage is measured on the low-tension side (compensating for drop through the transformer). Since, in the case of tap changing, the actual ratio of transformation is varied, it is necessary to also provide some device such as a small auto-transformer the ratio of which is correspondingly varied by a dial-switch operated from the mechanism. Such a device has been operating satisfactorily in the installation at Chester Station, already described.

In providing the usual differential relay protection, this change in the ratio of transformation must be provided for either by the use of an auto-transformer the ratio of which is varied with that of the main unit or by designing the turns of the relay for the mid position of the tap changer and setting the relay sufficiently high to prevent its operation on through short circuits.

Any failure of the mechanism that may damage the transformer winding thermally should be guarded against, but should one occur, it should be indicated by an alarm. In the case of the double-winding transformers at Chester this is accomplished by relays connected differentially between the two windings which operate when either winding is carrying all the load or when the two windings are in parallel on different taps. These relays in turn operate a definite time limit relay which at the end of one minute gives an alarm.

Conclusion

The author believes that there is a real field for transformer tap changing under load and that this will continue to increase with the expansion of interconnection and superpower. Development will be stimulated as its possibilities are more widely recognized and appreciated.

Acknowledgment is made of the assistance of Messrs. R. A. Hentz, Raymond Bailey, B. E. Hagy and Jos. I. Tabakin, of The Philadelphia Electric Company, in the preparation of this paper.

WHY NOT DISCARD THE TERM "POWER FACTOR"?

An attempt to analyze or compare power-factor conditions shows how futile it is to employ the term "power factor." Its use in most analyses requires too many qualifying appendages. As a result, when one has finished an analysis he wonders whether he should have used average or weighted power factor or whether either is the desirable unit.

"Kv-a." and "kv-a-hours" are much more useful if they can only be recorded in the form desired. Considering "kv-a-hours" alone, its proportion to "kw.-hours" on a peak-load day, during the peak-load hour, or on an average summer day, would indicate what excess voltage drop and excess equipment, including apparatus and circuits, was made necessary by poor power factor alone. The ratios of the squares of these values would indicate the relation of heat losses under different conditions of operation. By trigonometry the reactive kv-a. could always be obtained to ascertain what corrective kv-a. is necessary on any feeder. While the power factor may vary with different loads on apparatus, the reactive kv-a. will always be approximately the same with the same equipment connected.

What is to prevent electrical engineers from talking about magnetizing current, reactive kv-a. or kv-a-hours, instead of continuing the use of the old term "power factor," which is valuable for any set of conditions, but leads into a maze and is too indefinite for most studies, whether they be technical, economic or financial?

—*Electrical World.*

Discussion at Spring Convention

ELECTRICAL SHIP PROPULSION[1]

(Harvey and Thau)

St. Louis, Mo., April 16, 1925

V. Karapetoff: The Diesel engine is essentially a constant-speed prime mover, and I should like to ask Mr. Thau about its application to the tug service, which, to me, is essentially a variable speed application, and also one involving a high slip, either in the electrical equipment or between the propeller and the churning water. With a d-c. drive, the Diesel engine can run at a constant speed, and the d-c. motor on the shaft can be controlled either by a series resistance or by a resistance in the field circuit. But I should like to know how this is done with a-c. drive, or is the a-c. drive not suitable for the tug service?

I wish also to mention a specific engineering problem which arises in the turbine-electric marine drive with either induction or synchronous motors. The induction motor has a circle diagram, but this diagram holds true only at a constant current or constant voltage. In marine drive we have neither. If my information is correct, generators are usually operated at a constant field current, in which case the terminal voltage between the motor and the generator varies with the torque on the propeller shaft. As this torque increases, the generator voltage dies down. In computing the performance characteristics of such a set, we have a rather difficult engineering problem, because the internal reactance in the generator and its armature reaction have to be considered, as well as the constants of the motor itself, the voltage between the two machines being at the same time a function of the load.

C. H. Giroux: I shall confine my remarks to river boats, as I believe that many engineers from this vicinity are interested in this subject.

The authors have omitted reference to one vessel which I believe deserves mention, as it is one of the pioneers in its field; namely the *Chenoka*. The *Chenoka* is a stern-wheel towboat, 77 ft. long, 10-ft. beam, and having a displacement of 32 long tons.

During 1920, the Cincinnati district of the U. S. Engineer Department equipped it with electric propulsion, using a 25-kw., gasoline-electric generating set, a 50-h. p., shunt-wound motor, and rheostatic control. For experimental purposes, a producer was installed and the engine operated on coal gas for a short time. The intermittent service in which the vessel was used, however, was not conducive to good results with the producer, and it was finally abandoned. Kerosene was used with a fair degree of success, but the advantage of lower fuel cost was offset by operating difficulties, and the engine is now being run on gasoline only.

While the equipment on the *Chenoka* does not conform to present marine standards in many respects, it has been in successful operation for a sufficient length of time to prove the reliability of electric drive for small river boats where the maintenance is not always the best, and where skilled operators cannot be employed for monetary reasons.

Based on the results obtained on the *Chenoka* and the Diesel-electric towboat, *J. B. Battle*, the U. S. Engineer Department is designing and constructing a number of stern-wheel towboats for use on the Mississippi and Ohio rivers. These boats will have improvements incorporated which should cause them to show even better results than those now in operation.

The most important of these improvements is the adoption of a propulsion motor, the speed of which may be varied over a wide range by field control, keeping the horse-power output constant. Ward Leonard control for slow-speed running, accelerating and reversing is, of course, retained. The variable-speed motor allows full rated output of the prime movers to be applied to the wheel at any speed of the towboat from standstill to light-running speed.

This is a decided advantage over any direct drive system where the horse power varies with the speed of the paddle wheel. From tests on existing towboats it is estimated that the effectiveness will be increased as follows:

Conditions	Variable-Speed, Electric Drive	Other Systems
Towing effort at standstill, per cent....	160	100
Speed towing four barges, per cent.....	110	100
Speed light without tow, per cent......	100	100

The first condition means that the tow can be accelerated more quickly and a heavier tow can be maneuvered.

The second condition shows a substantial saving in time when handling heavy tows.

The third condition shows that there is no sacrifice in running light speed for the gain in towing ability.

As the weight of the tow is often limited by the rapidity of the current when going up-stream, the extra towing effort available may enable the boat to handle heavier tows and to make "double tripping" unnecessary in the more rapid parts of the stream.

Considerable attention has been given to the control equipment, with the idea in mind of simplifying the methods of operation. The next towboats built for the U. S. Engineer Department will be equipped with automatic control from the pilot-house. By means of a single master switch, the boat may be maneuvered from full speed ahead to full speed astern without the necessity of watching electrical instruments or without danger of overloading the prime movers. No adjustment of rheostats in the engine room will be required for handling tows of various weights, as this is accomplished by the automatic devices.

An attempt is being made to place the design of river boats on a more scientific basis than has been possible heretofore, not only by means of complete model tests, but also by securing operating data from vessels in service. Electric drive, with its attendant possibilities for accurate measurement of power under daily service conditions, will do much to aid the investigators in this attempt.

A. A. Coyle: The propulsion of vessels by electric power is yet in its infancy, and like most other inventions, will be improved from time to time as defects in design and mechanism develop. This is the history of mechanical devices, and while there may be exceptions, we know of none in which the original design has not been changed to meet the conditions under which they must operate.

Generally speaking, electric drive for boats has passed the experimental stage, the installations made in the past and the successful operation of the various craft in which the installations were made, demonstrate its practicability and efficiency for boat propulsion.

Boat owners and operators have been slow in adopting new or untried methods for the operation of their boats and the principal reason for their conservatism will be found in the fact that the margin of profit is so slight that experimental work could not be undertaken, or even considered. Operating costs have more than doubled, and the receipts or advance in rates have not been in the same proportion, resulting in what is termed hand-to-mouth existence. With conditions unfavorable for successful operation of their boats, many have disposed of their interests, while others have continued the operation of their fleet with th

1. Complete paper available in pamphlet form only. Synopsis published in this issue.

hope that means for reducing the operating costs would eventually be provided. The successful operation of boats propelled by Diesel-electric power has inspired boat owners to investigate the advantages of Diesel-electric over the steam drive, the result of which has convinced many that the Diesel-electric power is what is needed if river traffic is to be revived, and the operation of river craft made profitable. Diesel-electric power for river boats has the following points in its favor:

a. Economy in operation (fuel and labor)
b. Efficiency in maneuvering
c. Concentration of responsibility in one man
d. Positive control
e. Insurance reduction
f. Cleanliness
g. Requires less deck space
h. More deck space available, due to storage of fuel in hold
i. Equal torque at all speeds

With the facts above mentioned brought to their attention, and the necessity of reducing operating expenses to the minimum to realize a reasonable return on their investment, many boat owners have decided to install Diesel-electric power on all boats to be constructed by them in future, and in some cases will remove the present steam installation and install Diesel-electric power. This will tend to revive river traffic, and the means by which the operators of river boats may recoup themselves for some of the losses sustained in the past.

As is generally known, there are in use three methods for the application of electric power to stern-wheel boats, *i. e.*,

a. Longitudinal shafts with bevel or worm gears
b. Chains running over sprocket wheels
c. Pitmans, similar to those in use for steam drive

For many reasons, the first and second methods are not satisfactory where applied to stern-wheel boats operating on rivers where silt and drift are prevalent. The construction, and the bracing of the paddle-wheel supporting beams must necessarily be light to insure the desired draft of boats for shoal rivers, and the wheel being subjected to both vertical and longitudinal movement (however slight) tends to throw out of alinement the drive shafts and gears, with a corresponding loss of power. There is also the danger of drift and broken buckets coming in contact with the shafting, which often causes serious damage to the parts and quite frequently disables the boat until such time as the parts can be unshipped, sent to a machine shop, repaired and replaced. As the boat is often some distance from a shop in which repairs might be made, it is evident that delay in such cases is very serious to the owners. For these reasons it has been the aim of designers and owners of stern-wheel boats to eliminate all rods, cams and gears from on or near the wheel. It may be said by those advocating the chain or gear drive that all parts may be housed for protection, but even though this housing may protect the parts so easily affected, they cannot prevent the vertical or longitudinal movement of the wheel, which tends to throw the driving mechanism out of alinement. The housing must necessarily be made very strong to withstand the usage to which they will be subjected, for if this is damaged it is a serious matter.

The third method, (pitmans) to transmit the power from the motor to the wheel shaft is in our opinion the best yet devised. However, the drive as applied, is not entirely satisfactory to many boat owners and it is thought that a much better arrangement can and will be designed, eliminating the objectionable features.

The installation on the U. S. Towboat, *J. B. Battle*, includes a large and very long counter-shaft, extending across and nearly the width of the boat. To this are attached the cranks and a large spur gear. This gear is attached to the counter-shaft at about the center, thus necessitating three or more bearings, a very bad feature when one takes into consideration the light construction of the hull to which the counter-shaft bearings are secured, because it is then impractical to provide foundations with sufficient rigidity to insure proper alinement—an essential feature in fuel economy. And while the shaft alinement is not observable, it is more or less out of alinement, the amount depending upon the rigidity of the hull to which the shaft bearings are attached. A single motor is used for the full power required to rotate the paddle wheel at the desired velocity, and, as all of the power is applied to the large spur gear attached to the counter-shaft, it is evident that when one of the pitmans is on center the full power of the motor is transmitted to the other pitman which, for *steam drive*, would be designed to transmit only half of the actual horse power developed. Under no circumstance could more than half the power be applied to either pitman. Therefore, it is evident that pitmans, cranks and wrists for the electric drive as now applied must be proportionately larger than those in use for steam drive with equal power, to care for the increased thrust. This addition for increase in strength and weight of the pitmans, cranks and wrists occurs where it is most objectionable, as our great problem is to keep the stern of the boat up, in order to obtain maneuvering benefits. With the counter-shaft extending across the boat, and, necessarily, three to five feet above the deck, the space aft of the counter-shaft is not available for other purposes.

We are of the opinion that it is possible to design, and apply a more efficient and better general arrangement than is now in use, and we are working with that end in view. We believe the power required to propel the boat should be in two units, (two motors) each acting independently on its own pitman, with a suitable control to cut out the current gradually as the pitman approaches the center, and again applying the current gradually immediately after the pitman passes the center, the application of power being similar to that now in use with steam drives.

There is a difference of opinion among electrical engineers regarding the practicability of such an arrangement, some contending that motors as now constructed, would not stand up under such usage but, as the motor is not stopped, or even perceptibly slackened, it occurs to us that if motors as now constructed will not meet the requirements, a motor can be built that will.

R. A. Beekman: My comments refer to several points in the paper as indicated in the following notations:

Paragraph beginning "The justification of the turbine electric system, etc." Taking transmission efficiency in its broadest sense, that is, from the boiler to the propeller, the efficiency of the turbine electric system using a-c. machinery is in many cases equal to, and in some cases better than, the corresponding transmission efficiency obtained with geared turbines. Namely—the geared-turbine losses including the losses in the gears, reversing element, cross-over connections, additional bearings, packings and lubricating oil required over and above that required by the turbine electric system, give a total of from 7 to 10.3 per cent of the total shaft horse power.

In the case of the turbine electric drive, the total loss including losses in the motor, generator, control, and cables, and the power required for excitation and for ventilation of the main machinery, is approximately 7.6 per cent of the power delivered to the propeller shaft. Furthermore, where single reduction gears are used, the turbine efficiency on the Rankin cycle should be higher in the case of the turbine for electric drive than the turbine for geared drive, since the former turbine can be run closer to its most economical speed.

Paragraph beginning "Turbines with reversing elements, etc." The larger diameter necessitates larger radial clearances with reaction-type turbines, but if impulse-type turbines are used, radial clearance is not a factor.

Paragraph beginning "With turbine electric drive alternating current is more satisfactory, etc." Greater emphasis should be given to the advantages of d-c. turbine electric drive for the smaller ships where turbines are suitable. The important advantage is that a constant-speed turbine generator may be used

which permits taking the auxiliary power either from the main generator or from the direct-connected exciter. We also have all of the advantages incidental to the flexibility and reliability of the Ward Leonard system of control repeatedly referred to in this paper.

Paragraph beginning "The electrical machinery is practically the same as used in land installations," etc. There is an increasing tendency to run the electric auxiliaries from the main propulsion generator, in order to get auxiliary power at approximately the efficiency of the main unit.

Paragraph beginning "A 75-kw., 115-volt, 900-rev. per min. exciter," etc. This exciter also supplies power for miscellaneous auxiliaries.

Paragraph beginning "The Ward Leonard system of voltage control is by far the most satisfactory," etc. The Ward Leonard system is not necessarily the most satisfactory system, inasmuch as the rheostatic-control system has been used most satisfactorily on at least five ships. The rheostatic control was selected after careful consideration of the special conditions to be met. Where two or more generators are used one generator may be operated at constant potential, furnishing power for excitation and the auxiliaries as well as for propulsion, and the second generator may be operated on the voltage-control basis. This is a combination of rheostatic and Ward Leonard control where all maneuvering of the ship between 50 per cent and 100 per cent propeller speed is obtained on a Ward Leonard, and hence, highly efficient, basis.

Paragraph beginning "With the series connection of generators," etc. The statement regarding Ward Leonard system being less expensive may be somewhat misleading, due to the fact that the necessary exciters should be considered a part of this system, both as regards expense and complication.

Paragraph beginning "The control board contains suitable switches," etc. In the early days of Diesel-electric drive it was thought to be desirable to have a time-delay element for limiting the speed of operation of the control, but experience has shown that this is unnecessary and that we can go from full speed to the stop point without hesitation.

Paragraph beginning "With this type of drive provision is usually made for both pilot-house and engine-room control," etc. Another advantage of pilot-house control of tug boats comes in being able to take slack quickly out of the tow ropes and uniformly accelerate the tow without objectionable strains.

Paragraph beginning "Flexibility and Reliability." The number of generators is not limited by either the rheostatic or Ward Leonard system of control.

Paragraph beginning "It will be noted that the control for these boats," etc. The *Fordonian* has a control which is a combination of Ward Leonard and rheostatic system, as described under Comment No. 6.

Paragraph beginning "The *Standard Service* equipped with Pacific Diesel and General Electric machinery, etc."

The *Standard Service* was put into commission in March, 1923, and similar tankers, the *Alaska Standard* and the *Hawaiian Standard*, were put into commission in December 1923, and February 1925, respectively. This is a good example of an owner having added Diesel-electric ships to his fleet after experience with the first boat.

W. E. Thau: Professor Karapetoff struck on two vital points in connection with electric drive; one relating to the flexibility of direct current for tug boats and the other the unit design of an a-c. propulsion system.

If an attempt is made to use alternating current for tug boats and that class of service, we should have a plant which is extremely inflexible in comparison with direct current; and, furthermore, if we had multiple-unit arrangements of engines, it would be necessary to operate a-c. machines in parallel, which is questionable, regardless of the arrangement; that is, the idea of operating Diesel-driven, a-c. generators parallel on board the ship. In addition, we would lose about 80 per cent of the flexibility which the d-c. system possesses for tugboat work.

Furthermore, by using the d-c. system, say with two generators and a single- or double-armature motor, we are able to operate that tug with one unit in case of failure of one of the engines. In case of failure of a direct-connected engine, the situation is helpless. This particular advantage has proved to be of great practical value in connection with the *P. R. R. Tug No. 16*, operated by the Pennsylvania Railroad in New York. On one occasion they had trouble with an engine and that engine was shut down and the tug operated on the remaining engine, without those for whom the towing work was done knowing whether one or two engines were in operation.

With the d-c. system, the Ward Leonard system of motor speed control is used. This permits the use of simple generator-field rheostats for providing a large number of speed values in each direction in the most economical manner. The engines run at constant speed. The generators are connected in series, thus dispensing with the necessity for parallel operation. The electrical efficiency is maintained near the full-load value throughout the entire speed range from 10 per cent to 100 per cent speed. In other words, the combined electrical efficiency curve is very flat.

In the case of alternating current, the speed control would have to be obtained by engine control or rheostatic control. The former is no improvement over the direct-connected engine and the latter is both complicated and wasteful.

Furthermore, the d-c. system permits full power to be had from a fractional number of engines, whereas with a-c. the engine speed would have to be reduced to suit the load in the case of operation on less than the full number of engines.

In case of turbine electric drive, the question of torque couple between the motor and generator was brought up. This is something that would probably be overlooked by the uninitiated, but the fact is that the whole system from turbines to control must be designed as a unit and the functions of each part correlated.

The pulling out of step of an a-c. drive is not due to the fact that the motor breaks its torque couple. The motor is designed for about one and three-quarters pull-out torque, and that gives it plenty of margin, so long as it is provided with a constant voltage. The real cause of pull-out between the generator and motor is the collapse of the generator voltage due to overload which Professor Karapetoff has mentioned.

In all land installations, we have a relatively unlimited supply of power and the generators are sufficient in number and in size to supply the total demands and take care of peak loads. Such machines are usually designed to provide about 5 per cent to 10 per cent torque margins at the nameplate rating.

In the case of ship drive, when the load varies with sea conditions, maneuvering, and so forth, we must provide an ample torque margin in the generator. That is provided by additional excitation. If we operate with too great excitation, the efficiency of the motor drops considerably. This condition is very pointedly shown in certain tests that are made on board battle ships, and are known as excitation, or drop-out tests. We start with a high generator excitation and gradually decrease it until the motor and generator torque couple is broken. The power input to the motors at the start of the test is appreciably higher than when zero torque margin is approached (approximately 10 per cent) and, therefore, it is uneconomical to run with too much torque margin. That condition has been recognized in the Navy, and steps have been taken to operate vessels with an economical torque margin. That margin is indicated by an instrument called a stability indicator which shows the torque ratio at any instant.

Mr. Barrister brought out a point in connection with the steering gear on board the ship. This is another case where the complete facts must be known, and the motor, controller, and resistors designed as a unit and not with a motor picked here, a

controller there and a resistor some other place. As already mentioned the various units picked at random have proven a failure. It is a definite application problem and where early failures have occurred, they can almost invariably be traced to the fact that the equipment has been taken out of stock and put on board the ship. Those of us who have had experience with the sea conditions know that that stock equipment does not work. When such care is necessary in the design of the equipment, it is no wonder we ask for competent electricians to take care of this electrical equipment.

Mr. Giroux is in a very good position to discuss the river-boat situation, being the electrical engineer for the United States Engineering Department at Washington, and having had considerable to do with practically all of their engineering work in that line, which he has so ably described.

The War Department is investigating and pioneering in that field and so soon as they prove to the private owners that the electrical is the proper system, we shall see private boats driven by the Diesel-electric system. Of course, the War Department is in a better position to make study and investigation of that kind because of its organization and funds. We civilians pay the taxes and they do the pioneer work in that and other fields. The results benefit every citizen in the country. The War Department is doing wonderful work along these lines, even though most of us are not aware of it.

Mr. Coyle has enumerated the advantages of electric drive for river boats from a designer's and builder's point of view, and it will be noted that he has confirmed, to a great degree, the claims for this type of drive in the paper. Mr. Coyle has spent practically his whole life in this work, and so is in a good position to analyze the situation.

We feel that he is correct in his statement, that gears and chain drives are not as applicable to stern-wheel, river-boat propulsion as the pitman drive. It represents a very intricate problem and one which will require much close study before it comes to a high degree of perfection. The fact that the electric motor tends to produce constant torque introduces a problem for consideration in design of pitman. If it were possible to regulate the motor performance similar to that of a steam-engine performance, it would help things along considerably. There has been devised a special form of pitman connection using two pitmans on each side of the wheel, and in each pair the pitmans are placed 180 deg. from one another. With that arrangement, having the other side at 90 deg., we have a system which will develop a constant turning effort on the wheel. That has a further good point, in that the wheel bearings do not have to be anchored solid. That eliminates a lot of trouble that might arise from any other pitman design.

I should like to make just a few remarks in connection with Mr. Beekman's discussion of the paper. I thought the paper recognized the suitability of d-c. equipment with turbine electric drive. We stated that the application for that type of equipment was confined more to the vessel requiring very restrictive maneuvering. For a vessel, such as a tug or a ferry, operating in unrestricted water direct current is better suited than alternating current, and while the cost is more, the installation of the direct current is justified by its increased flexibility.

The question of rheostatic control versus Ward Leonard is one that can probably be discussed for a long time. Some of the present rheostatic-control vessels are handicapped. In small installations there is no question that the rheostatic-control system can be used. I think that was mentioned in the paper and an example cited. Those applications that require constant voltage can be supplied by exciters of suitable capacity driven from the main engines.

The time-delay device, which was referred to, I believe, is absolutely necessary and essential on many classes of ships. So far, the application of Diesel-electric drive has been confined to slow-speed, coarse-line, low-inertia vessels, but when this type of drive is applied to fine-line boats with high powers, requiring considerable torque to stop them, some kind of a device will be required to regulate the current. D-c. machinery cannot be abused to the same extent as a-c. machinery. Mr. Giroux touched on that point in his discussion, and described how the U. S. Engineering Department expects to provide for a current-regulated device on its tow boats.

In the case of direct-connected impulse turbines the large disk area resulting from the large-diameter wheels is a factor contributing to additional losses which are comparable to the radial-clearance losses in the reaction turbine.

Auxiliary power cannot be taken from main units during maneuvering if the Ward Leonard system is used.

In any event, exciters or direct-connected auxiliary generators are very desirable for supplying auxiliary load, and they may just as well be made large enough to supply excitation for the Ward Leonard system. Therefore, they are not an added complication.

Discussion at Annual Convention

LATEST DESIGN AND PRACTISE IN POWER PLANTS[1]

(ALDEN)

SARATOGA SPRINGS, N. Y., JUNE 23, 1925

A. L. Mudge: An extremely interesting and important matter has been dealt with in this report, viz.: the limiting size of hydroelectric units. On the accompanying chart have been plotted the recommendations (included in the report) as made by three turbine builders, viz.: Newport News Shipbuilding Company, S. Morgan Smith, and Allis-Chalmers Manufacturing Company.

Head has been plotted horizontally up to 350 ft., and the vertical scale shows turbine discharge up to 10,000 cu. ft. per sec. Discharge of these turbines has been calculated by the simple approximate formula cu. ft. per sec. $= \dfrac{10 \times \text{H. P.}}{\text{Head}}$.

All three curves have pretty much the same general form, indicating that the maximum discharge for which turbines can be built is for heads of between 40 ft. and 60 ft., with rapid decrease as lower heads are approached and a gradual tapering off of discharges at higher heads.

On this chart have been indicated eleven hydroelectric units which I believe to be the largest units built from point of view of discharge capacity per turbine at heads up to 300 ft.

The Cedars and Keokuk turbines, constructed about thirteen years ago and having a discharge of about 4000 cu. ft. per sec.; through a single Francis runner, have held the record for this type of runner until this year when the Ottawa River Power Company installed a unit under 60-ft. head having a slightly greater discharge.

Manitoba Power Company and St. Maurice Power Company units at LaGabelle, with propeller-type runners, have gone up to 5000 cu. ft. per sec.,—the greatest discharge of any turbines in existence.

The Niagara Falls Power Company's units and those of the St. Maurice Power Company probably represent the greatest advance in hydraulic-turbine practise since the Keokuk units

1. A. I. E. E. JOURNAL, November, 1925; p. 1178.

were built, and it will be noted that all manufacturers express the opinion that units substantially larger than those already built are feasible.

On the ninth page, Mr. Hanker gives a tabulation of the economic design limitations of vertical water-wheel generators, but it is a pity that he stopped just before getting into the range that would be of greatest value to those of us who are interested in moderate and low heads,—say from 100 ft. down. It would also be interesting to have a similar table for 25-cycle generators.

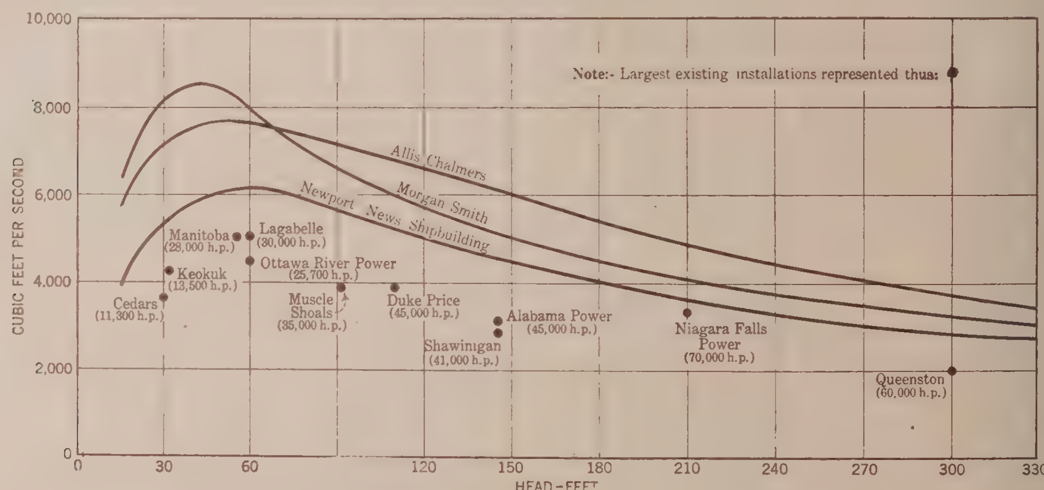
The report suggests that there is a tendency to get away from direct-connected exciters on main generator shafts. From the study of a number of important stations, a fair conclusion is that the reverse is the case, due to the present reliability of the direct-connected exciter, and of the thrust bearing, and also due to the desirability of making each main unit in station self-contained and independent. Referring again to the chart on which are plotted particulars of turbines in eleven large and representative developments at heads of 300 ft. and under, the units in the majority of these plants have direct-connected exciters. As to those using separately driven exciters, Keokuk and Cedars operate at the extremely low speeds of 57 and 55 rev. per min. respectively which would have involved very expensive direct-connected exciters. Also they were designed thirteen or fourteen years ago, when d-c. generators were not so reliable as they are now.

Niagara Falls Power has a special exciter system depending upon an a-c. service generator directly connected to the main generator shaft. This would seem to introduce at least as much complication as a direct-connected exciter. In all of the remaining installations, the exciter is directly connected to the main generator shaft.

In the North we do not favor the idea of depending entirely on separate water-wheel-driven exciters. In plants subject to ice trouble, these small turbines would be the first to go out of commission.

G. L. Knight: Mr. Alden has shown what tremendous strides have been made in the design of power plants and power-plant machinery especially turbo generators within the last few years, results which have been brought about by the manufacturers with the cooperation of the operating companies. In connection with this I should like to record something that has happened since the writing of the report; that is, the purchase by the Brooklyn Edison Company of what I think is the largest turbo-generator so far contemplated. The Brooklyn company has purchased from the Westinghouse Company as the fourth unit for its Hudson Avenue generating station an 80,000-kw. machine. The unit will be of the cross-compound type, both high and low-pressure turbines will be of 40,000-kw. capacity, operating at 1800 rev. per min. This machine has been purchased for steam conditions of 375-lb. and 700-deg. total temperature, whereas the other units are on a basis of 275 lb. and 200 deg., which is about 612-deg. total temperature.

This new unit has some interesting points in connection with it, in that the Westinghouse Company offered a machine which can be changed from a peak-load machine to a base-load machine, the best point being at either 45,000 kw. or at 60,000 kw. For instance, the machine can be made a base-load machine now and, with a very small field change, can be altered to a peak-load machine, after the second or third year if still more economical machines should be purchased and it should be desired to change this one to a peak-load machine, that is to have its point of maximum economy lower down on the load curve.



Limiting Sizes of Hydraulic Turbines (Single Runner Vertical)

R. E. Argersinger: I should like to join with one of the previous discussors in taking exception to the Committee's rather implied statement that direct-connected exciters are going out of favor. I have recently had occasion to analyze various excitation schemes in connection with some very large water-wheel-driven generators; that is, generators in the order of 40,000-kw. at 90 rev. per min. We have considered many exciter layouts, including motor-generator sets driven from generators connected to water wheels; also from a-c. generators on the main generator shaft and from transformers directly connected with the generator winding, as well as water-wheel-driven exciters, but we found that there was a substantial saving obtained by the use of direct-connected exciters on the main generator shaft. We apprehended some trouble in securing voltage regulation with automatic regulators from such slow-speed direct-connected exciters, but after checking with the manufacturers this seemed to present no serious difficulties. Our conclusion was that, for the case studied, the direct-connected exciter permitted the simplest, cheapest and most efficient arrangement.

R. E. B. Sharp (by letter): In connection with this report we should like to submit from the William Cramp & Sons Ship and Engine Building Company the following data showing the

estimated maximum horse power of water-wheels for different operating heads and speeds:

Head (Ft.)	Horse power	Rev. per Min.	Governing Factor	Type
20	15,250	50.0	Runner diameter	Concrete casing
40	43,000	70.6	Runner diameter	Concrete casing
70	53,000	69.2	Runner diameter	Concrete casing
100	67,500	76.6	Thickness of metal	Plate-steel casing
150	95,500	85.7	Thickness of metal	Plate-steel casing
200	63,500	105.9	Size runner	Cast-steel casing
250	88,700	116.1	Size runner	Cast-steel casing
300	116,500	128.6	Size runner	Cast-steel casing
400	93,500	171.5	Thickness metal	Cast-steel casing
600	78,500	257.1	Thickness metal	Cast-steel casing
1000	55,400	450.0	Thickness metal	Cast-steel casing
1000	25,000	240.0	Size of jet	Impulse, two-runner overhung
2000	72,000	300.0	Size of jet	Impulse, two-runner overhung

You will realize, of course, that these values are subject to very considerable variation, and it is probable that the capacities could be increased after having made detailed studies of the various conditions. For the 20-ft. and 40-ft. heads, we would count on the propeller type of runner, and for the 70-ft. to 1000-ft. heads inclusive, we would count on the Francis-type runner. For the 70-ft. head, using the Francis-type runner, we are inclined to think that the capacity of the unit can be increased somewhat above the value given, but would hesitate to increase it at this time until a layout could be made for this condition. For the 100-ft. and 150-ft. heads with plate-steel casings, we have considered that the limiting factor is the thickness of the metal in the casing. For heads of 200, 250 and 300 ft., we have counted on turbines of the same size as the 70,000-h. p. Niagara units, which we feel for the conditions represent about the maximum allowable capacity. In reference to the 200-ft. and 250-ft. heads, we feel that the capacities could be increased above those given. However, we do not believe it would be economically practical owing to the large number of sections into which the casing would have to be divided and the resulting high cost. For heads from 400 to 1000 ft., we have considered that the thickness of metal in the casing would be the governing factor.

We would be inclined to think that to permit the metal in the cast-steel casings to increase beyond tried thickness might not only introduce difficulty in obtaining the desired stresses in the greater casing thicknesses but also might introduce problems in bolting the casing sections together which might be impracticable to overcome.

We are inclined to feel, however, that study would permit of a greater unit capacity than 55,400 h. p. for 1000-ft. head, although we believe it will be well to adhere to this value in actual data that you may desire to use. We have given data for the 1000-ft. head for the Francis turbine and also for the impulse type. If the water has any appreciable amount of foreign matter in it, particularly in the form of sharp sand, the impulse type should be used. These impulse wheel units would be in the form of two-runner horizontal-shaft units with the generator between them. The capacity of each wheel would be half that given in the horse power column.

V. E. Alden: The statement submitted by Mr. Mudge, taken together with the statements from the different manufacturers, give us a very good idea as to limitations in the size of water-wheel-driven generators.

Mr. Knight has told us of the 80,000-kw. turbine just ordered for the Hudson Avenue Station of the Brooklyn Edison Company. I wonder if the decision to use this 80,000-kw. turbine in the extension to their station in preference to a duplicate of one of the 50,000-kw. turbines now in operation, was indicated by the possibility of reducing the investment charges per unit of output.

The questions raised by Mr. Mudge and Mr. Argersinger would indicate that perhaps we did not quite accurately gage the trend of the industry in our statement "there is considerable tendency to get away from direct-connected exciters on the main generator shaft, making the main generator easier to dismantle and reassemble," as concerning details of design there will always be differences of opinion and variation in local conditions will indicate the necessity of differences in treatment. It is of interest to note in connection with these questions raised by Mr. Mudge and Mr. Argersinger that there is a rather definite trend towards the more extensive use of shaft-driven exciters in connection with steam-turbine-driven generators.

In closing this discussion I wish as chairman of the Committee on Power Generation to express my appreciation of the work done by the members of the committee, by the representatives of the manufacturing companies in the preparation of their statements and by R. C. Dannettel and D. Ballard, in the preparation of the very complete bibliography, which forms an appendix to the report.

OSCILLOGRAPH SOLUTION OF ELECTROMECHANICAL SYSTEMS[1]

(NICKLE)

SARATOGA SPRINGS, N. Y., JUNE 26, 1925

R. E. Doherty: Anyone who has wrestled with differential equations in attempting to solve those of higher order must certainly be impressed with the possibility of having an electric circuit solve them, and an oscillograph plot the solution. This is precisely what Mr. Nickle's scheme does.

The extent to which it has been developed in this paper is, in my opinion, only a beginning, touching as it does, only those cases in which the phenomena can be represented by circuit elements which are constant. However, the scheme is not limited to such cases. The method is perfectly general and applicable to any problems for which circuit elements of proper characteristics are available.

Regarding its present possible application to problems involving constant circuit elements, it should not be inferred from the paper that it is applicable only to problems of power transmission; rather, it applies to many other problems involving mechanical oscillation; for instance, the flywheel problem of synchronous machines connected to reciprocating apparatus; short-circuit forces in busbars, etc. Such problems are beautifully solved by this method.

I wish to call attention, also, to its educational value in drawing out the parallel between various physical phenomena. In this, it is of great value and I commend it to the attention of educators.

R. D. Evans: In regard to the application of Mr. Nickle's work to the solution of the problems which are facing the industry at the present time—such as the stability problem there are a number of points which I would like to discuss. The method as described in the paper is of limited application in the study of stability, for the reason that the fundamental assumptions involve power relations proportional to the angle of phase difference between e. m. f.'s instead of a trigonometric function of the angle. Stability is of importance in the vicinity of the limit, and for this condition the assumption that the power is directly proportional to the angle is entirely too crude for practical application.

The method described by Mr. Nickle has application in the determination of the hunting condition rather than for the stability condition where pull-out may occur. For the condition of hunting, the power changes in almost direct proportion to the angle, and the approximation that the power is directly proportional to the angle is sufficiently accurate for the purpose.

It is possible that Mr. Nickle's methods may be extended, not to solve the stability problem as a whole, but to solve a particular part. For example, it may be possible that his method may be applied to the receiving network of a transmission system in order to find a simple equivalent. Such a possibility seems likely because the power limits of the individual parts of the

1. A. I. E. E. JOURNAL, December 1925, p. 1277.

receiving network are relatively high in comparison with the power limits of the transmission network. Consequently the phase difference is small and the approximation assumed in this paper is sufficiently good for the purpose Having found a simple equivalent of a receiving network, the problem of determining the stability would be much simplified and could be handled analytically from this point.

We have been working along the same general lines, but in a somewhat different manner. Instead of converting the electromechanical transients to an electrical transient, we have sought to convert the electrical-mechanical transients to a transient of a mechanical system. One of my associates, Mr. Griscom, has investigated a mechanical system which avoids the limitation in Mr. Nickle's paper, due to the power being proportional to the angle of phase difference. Mr. Griscom was able to represent the trigometric function accurately. In the original form of the method, there were limitations due to the inability to represent losses with absolute accuracy.

These comments are made merely to point out the limitations in the method so far developed and described, and with the hope of stimulating further work along these lines for the electromechanical problem which Mr. Nickle has studied is one which in general cannot be solved analytically, but must involve either a solution of the type which Mr. Nickle has presented or involve a method of simplifying networks, so that the system, as a whole, will be sufficiently simple to handle analytically.

C. A. Nickle: The differential equations for any electrical circuit are linear if the values of inductance, capacitance and resistance remain constant. Evidently, such electrical circuits offer a rigorous solution for only those systems which may themselves be represented by linear equations.

The equations for a transmission system are not linear and hence the method cannot be used for values of power near the power limit. However, for values of power well below this limit, such a system may be represented for all practical purposes by linear differential equations and the equivalent-circuit method may be used. In this way the effect of various types of disturbances, such as dropping a generator, opening a line section, adding load, etc., may be studied. The relative severity of different types of disturbances, the effect of various physical constants on the behavior of the system, etc., may be investigated.

It should be realized, however, that the investigation of power-transmission problems is only one of the many possible applications of this method of solution. For instance, the sustained oscillation of synchronous machines connected to reciprocating apparatus may be easily and accurately determined by this method.

As already emphasized, the use of constant values of inductance, capacitance and resistance limits the method to systems represented by linear differential equations, but the use of circuit elements which vary in accordance with certain prescribed laws is quite within the range of possibility, thus making the method applicable to systems which are not linear.

Discussion at Swampscott Regional Meeting

INVESTIGATION OF HIGH-TENSION CABLE JOINTS[1]

(Davis and Crowdes)

Swampscott, Mass., May 8, 1925

A. P. Thoms: I do not see why so much stress should be placed on the dielectric loss in a joint. E. S. Lee, in a paper before the A. I. E. E. Midwinter Convention[2], stated that the dielectric-strength test is the most important and the best test available at the present time; that indications are that the present standardized voltages should be increased and that increasing the application of the test two or three minutes is of doubtful value. The authors of this paper have used the standardized dielectric-strength test with the application increased a few minutes, and this test, according to Lee, is of doubtful value.

All the dielectric-strength tests were made at room temperature. They should be made at maximum and minimum temperatures experienced in normal operation of the cable, and should range down to at least 5 deg. cent.

Accelerated life tests should, in my opinion, be at from 2.5 to 5 times the rated voltage. A single dielectric-strength test will not determine whether a joint will be satisfactory in operation. We should have a test on a joint similar to that required on a cable. If the joint is not subjected to tests to which we subject a cable, such as those required by the N. E. L. A. specifications, we should at least standardize our tests so that we can compare them. I do not see why all the tests were not made with three-phase voltage.

After a joint fails on a test, it is very important that the joint be opened and examined in very minute detail. In looking over the paper, I could not determine the complete path of carbonization. This seems very essential, as it affords information whereby we may improve the weak points in the joints, either by changing the material or by changing dimensions.

The voltage at which sounds of distress in the joint are heard is also very important as this voltage denotes deterioration in the joint. This can be taken with a stethoscope or with a long paper tube held to the ear. Most of the large operating companies are testing their long transmission lines with a kenotron or d-c. test. If the proper ratio between the a-c. and d-c. for the cable is 2.4, it may be 1.7 for the joint, and it is very essential that we know beforehand that these joints are not going to break down when the line is subjected to the initial acceptance test.

Mario Puritz: In giving the results of the last 33,000-volt joint described, Mr. Davis speaks of an "undercut curtain" joint. The patented Pirelli, three-phase joint, with undercutting and tightened paper rolls, is exactly of that type and has been used in Europe for many years. A full description of this joint may be found in the *Electrical Review*, London, August 10, 1923, and a further description with the latest improvements will be published in the Report of the Underground Systems Committee, N. E. L. A., to be printed this year.

About 200 of these joints for 35,000 volts have lately been installed in Chicago and Boston and it may be interesting for you to know some of the results obtained in the tests made in the laboratories of companies of this country. The test joints were all of about the same dimensions as those described by Mr. Davis which were filled with soft compound and differed only in that the lead sleeve was of smaller diameter and the reservoir on top. One joint was tested on three-phase, starting at 100 kv. and increasing 15 kv. every 30 sec. At 200 kv., after 5 sec., flashover occurred at the pothead. The voltage was lowered to 183 kv. and after 5 min., failure again occurred in the pothead. No sign of failure or carbonization was evident in the joint.

Four other joints of the same type were tested on single-phase, one conductor against the other two, with the lead at the middle point. The voltage was applied, starting at 120 kv. and increasing 10 kv. every 30 sec. One joint failed at 190 kv. after 21 sec. because of moisture in the compound. The three other

1. Complete paper available in pamphlet form only. Synopsis published in this issue.

2. Testing High-Tension Impregnated Paper-Insulated, Lead-Covered Cable, by E. S. Lee, A. I. E. E. Journal, February, 1925, page 156.

joints withstood the test potential of 200 kv. (the maximum pressure available) without evident trouble, and all failures occurred *in the potheads* as follows: after 20 min. at 200 kv. for the first; after 20 min. 15 sec. for the second; and after 20 min. 5 sec. for the third. No signs of carbonization were found in the joints.

Tests of the three conductors in parallel against ground were also made on three other joints with failures of the joints at voltages corresponding to 225,000, 242,000 and 225,000 volts, delta pressure.

In a long-time test run in single-phase, 100-kv., one phase against the other two and the lead at the middle point, another joint was perfect after 18 hr. and 18 min. when the cable failed at a bend, due to excessive increase of temperature of the dielectric. Of course, after this test some leaf-shaped carbonizations were found on the conductors all along the cable and in the joint, and these carbonizations showed on about 15 of the outside layers of the conductors, especially due to the single-phase test, but the carbonizations in the joint were not so deep as carbonizations on the cable.

The cables on which the test joints were made were either three 350,000-cir. mil. or a three 300,000-cir. mil., 35,000-volt, round conductor, 8 $\times$ 4.5/32-in. insulation, ⅛ in. lead and 3-in. overall diameter.

F. A. Brownell: The authors touch upon a vital point when they state that extreme care should be used in assembling the joint. We believe that is at least 50 per cent of the battle, and that the balance is in the right combination of materials entering into the joint.

From our experience with the right combination of low-dielectric-loss materials, we have found that the joint under stress is cooler than the cable. No actual temperature data are at hand, but in one case, after 13 h. at 105 kv., the cable and joint were examined and while the cable was actually hot, the joint was at only slightly higher than room temperature.

If the theory of graded insulation is sound, then we are not following the correct principle by wrapping varnished cambric upon paper of a lower specific inductive capacity, as this will place a higher stress upon the penciled surface. By plotting voltage-gradient curves using a specific inductive capacity of 3.5 for paper and 4.5 for varnished cambric and taking a point ⅛ in. back on the penciled surface of the paper, we get a voltage gradient of 12 kv. per cm. more than if paper had been used for insulation.

We made up two single-conductor joints with stepped insulation and with the same thickness of insulation in each case; we wrapped one joint with varnished cambric and in the second paper was used.

Failure in each case was at 190 kv. and the surface of the stepped insulation was badly burned. Then we were at loss to know whether this was due to reverse grading or to voids, due to the fact that it is practically impossible to obtain a tightly wrapped joint with paper. The one advantage in the use of varnished cambric is that it makes a tighter wrapping.

It might be of interest to compare two joints we made, similar in design to joint No. 3 except that we used a special material for wrapping over the connector to a level of the factory insulation and then wrapped paper over this, giving the same thickness of insulation as in joint No. 3.

Tests made on these joints with single-phase voltage are as follows: 100 kv., 4 hr.; 120 kv., 2 hr.-45 min.; failure in crotch of joint.

On the second joint, we held 80 kv. for 4 hr. and raised the voltage 10 kv. each hour. After 13 min. at 130 kv., failure occurred in the end-bell. This was repaired and when voltage was rapidly applied, failure occurred at the same place at 160 kv. The ends were again cut back and failure occurred again in the end-bell at 166 kv.

While the second joint did not fail, it showed signs of high stressing. The surface of one conductor at the edge of the belt was charred and the petrolatum had changed in color with particles of carbon throughout. In neither joint were there signs of charring along the surface of the stepped insulation.

Our experience has been that we could get higher breakdowns with a stepped joint and we have found that the average cable splicer will make a better and more uniform stepped joint than penciled joint.

We have examined joints that have been in service for a number of years and found that where they had been penciled very uneven surfaces were left to tape over.

In the first 33-kv. joint, the failure and signs of distress near the edge of the belt showed plainly that this was due to the tangential stresses at this point. In the second joint the insulation was extended back to the crotch and as this joint did not fail, we are led to believe that this is due to the added insulation.

I cannot conceive of overcoming tangential stresses by adding more insulation, but would rather borrow Mr. Ely's idea (and this was done) of using an electrostatic shield to overcome the tangential stresses and smooth out the voltage gradient at the edge of the lead sheath. In fact, by using this and some slight refinements, we have developed a joint that is apparently stronger than the cable.

In the final joint, the use of the Cleveland idea of undercutting the insulation and extending the connector to the level of the factory insulation is no doubt good, but it is limited to round conductors.

From our observation of splicing cable in the field we could not conceive of using a paper roll on three-conductor cables, for it is seldom that the three conductors can be brought out on a plane and a tight wrapping cannot be obtained.

As the authors have drawn no conclusions from their experiments, we are tempted to advance the following for them:

That with varnished-cambric wrapping and the joint filled with a hard asphaltum compound, the dielectric strength on short-time breakdown is high, but on life tests at high potential, a well wrapped paper joint filled with petrolatum will give a higher breakdown. This is perhaps accounted for by lower dielectric loss.

That the difference of tests between the joints shown as Figs. 13 and 15 could be accounted for in workmanship.

To sum up, we have concluded from our experimental work that for a 33-kv. joint (*a*) the material entering into the construction of the joint should in characteristics approximate the material in the cable; (*b*) we cannot get a tightly wrapped joint with impregnated paper and we have substituted a material with the same characteristics but more pliable; (*c*) tangential stresses at the termination of the lead sheath should be taken into consideration and it is believed that they could be overcome by the use of static shields or by the proper slope of the lead sleeve; (*d*) to get a well-filled joint, it must be filled under pressure and (*e*) the education of the splicer is very essential.

The only apparent objection to the use of petrolatum in filling joints is due to migration of the oil from the joint and this we believe could be overcome to some extent by using a petrolatum with a higher viscosity than possessed by that used at present and still having approximately the same dielectric strength.

Regarding Joint 13, Mr. Crowder asked us if we didn't believe that, due to the fact that he has added more insulation, he has given a higher dielectric strength to that joint? I don't believe so. We made up joints of different thicknesses of insulation. In two cases I recall we made up joints with 40 per cent more insulation than used on the cable; in another case, 65 per cent more, and by some peculiar coincidence, the joints with the most insulation failed at a lower voltage. If we plot a curve between voltage gradient and distance from the conductor we would find that we would get what could be likened to a saturation curve, or a point out from the conductor at which there is a very small voltage gradient—in fact practically no stressing,—

and from the little work I did I should imagine that they had just about reached that saturation point, or perhaps extended beyond it. In other words, they had more paper than they actually needed.

C. F. Hanson: In witnessing a dielectric-strength test on cable splices recently, I observed a phenomenon which, in my opinion, requires consideration.

The cable with the splice was bent into the form of a horse shoe and rested on wooden blocks supported by two I-beams laid across the top of a tank with the cable ends dipping into transformer oil in the tank. Between the sheath of the cable and the I-beam was an air-gap about 1 in. long.

The voltage was applied in steps and at each step the voltage was maintained constant for a given period of time. When the voltage reached a certain value a train of electrical discharges would occur intermittently across the air-gap. Coincident with these discharges, bubbles in the transformer oil would rise from the end of the cable. As the voltage was further increased, these intermittent discharges would generally cease for a while. Then later on, when the voltage had been increased still further, these discharges would again occur but with greater intensity. They would grow more violent until complete electrical breakdown occurred either in the cable or in the splice.

The phenomenon to which I alluded is the first train of discharges across the air-gap in conjunction with the bubbles rising in the transformer oil. The only logical explanation for this phenomenon which I can give, is as follows:

The discharges must have a high frequency in order that the impedance across the air-gap may be less than that of the return wire to the transformer. The thing which caused these high-frequency surges must have been a disturbance in the electric circuit. One source of disturbance is a surface discharge in the splice along the penciling of the original cable insulation. After a number of these surface discharges have occurred, the compound, which in this case was petrolatum, would have been heated locally and sufficiently to permit the compound to flow into the discharge path and temporarily oppose further discharges. The local heating would, of course, expand any air which might be present. The increased pressure could be relieved at the end of the cable, causing bubbles to rise. With further increase in voltage, the dielectric stress may become sufficient to expel the compound which had flowed in, when discharge would again occur. If the stress is sufficiently great to prevent the compound from flowing back into the path of discharge the splice will finally break down completely with a mass of carbonized compound. On the other hand the surges may break down the cable insulation before enough compound has become carbonized to form a complete short circuit in the splice.

A subsequent examination of one of the splices seems to substantiate the foregoing explanation. Apparently, this splice had not failed but the cable had. However, upon dissecting the splice, six layers of the original insulation and eight layers of the applied insulation were badly charred. Also a considerable amount of petrolatum was charred.

If the foregoing reasoning is correct then the breakdown voltage of a splice is that obtained when the first electrical disturbance occurs and not that obtained when a complete short circuit occurs. When the first disturbance occurs, the splice has become a menace in the electric circuit because it produces disturbances which are hazards to other electrical equipment in the circuit.

When reporting tests of splices it is frequently stated that the cable fails before the breakdown voltage of the splice is reached. If, however, the tests are interpreted as above suggested, it will probably be found that the splice has failed first.

C. F. Hood: The purchasers of high-tension cable have kept the manufacturers so busy in trying to meet their demand that the efforts which we have put forth in developing joints have followed somewhat behind the effort put into the development of cables.

In attempting to develop a joint which we feel can be recommended to the users of high-tension cables, we are now conducting a series of experiments similar to those outlined by Mr. Davis.

So far it appears that we can produce a wrapped joint which will be as good as the cable for which it is intended. We have made some experiments on wrapped joints in comparison with the so-called patented joints, and so far the wrapped joints have shown themselves to be considerably better than the type of joint built up with a barrier insulation.

Along these lines, I don't think that we can stress too strongly the necessity of having the jointers appreciate just what work they are trying to do. If they are not men who realize the importance of detail and following that very closely, as already pointed out, a good joint can be spoiled by a poor workman.

I think that a great deal can be gained by much closer coöperation between the manufacturers of the cable and the users.

A. H. Kehoe: The paper infers that due to the existing situation in joint design satisfactory operation of high-tension cable systems cannot be assured. I believe that satisfactory joints are now in operation on cable systems of all voltages for which we have been able to obtain cables. For ordinary joints we know that adequate factors of safety exist. For the high-voltage joints the factors of safety can only be estimated as we do not have good enough cable to test these properly.

The authors divide the essential properties of a good joint into three classes. We believe that simplicity of design is by far the most important element in comparing successful types of joints in service.

To further decrease the dielectric loss obtained with any practical joint today is not highly important, as cables in ducts run at a higher temperature than cables in manholes, so that the limiting condition is the heat of the cable in the duct.

Short-time applications of extremely high voltages may set up conditions not duplicated in actual service as certain types of dielectric have a high voltage-breakdown value for short-time applications, while other types do not. Results in practise at normal stress may thus give opposite results from such tests. In selecting test values it is important to ascertain whether the particular materials tested are stressed beyond their known breakdown values, rather than to make a large number of different joints some of which only demonstrate this breakdown limit which could have been positively predicted before the expense of testing was undertaken. The high-voltage accelerated-life test provides an important element of time saving in making tests but results are not directly comparative between varying types, as to normal voltage operation, particularly if high-voltage short-time values are used as is the case in these tests.

I believe that the essential element in cable joints and in cable installations is simplicity of design. From it, uniform results are most likely to be obtained. The greatest difficulty I have experienced in making joints is to be certain that all of them are tight, that is, that they are all waterproof. It is important in order to accommodate existing structures that a short joint be used. This same condition causes many companies to use sector cable and it is more difficult to obtain a joint with proper factors of safety on sector cable than on round-conductor cable. Simplicity of design also makes it easy to eliminate voids. I believe that many of the joints tested failed because of voids in the filling compounds. Testing a few joints all of different types or even a few joints of one type does not give a definite indication of the factors of safety unless they all target very closely to the same value on the test curve.

I should like information from the authors as to how they handled the end-bells in testing. The paper infers that dielectric loss was obtained first on long cable lengths averaging so much

per foot, and any increase was attributed to the joint. It is not clear how the dielectric loss of the end-bells was accounted for.

We have had several thousand joints of the fourth type tested by the authors, operating successfully at 28 kv. for over two years, and several other operating companies have had similar experience with this joint at similar voltage. The uniformly successful operation obtained with this type of joint for installation up to 33 kv. would not be predicted from the one joint tested.

In testing the first four types of joints, the dielectric strength to ground was tested, as three-phase potential should have been used to obtain the comparable results with the last three joints made from round-conductor cable. The initial voltage applied to the first four was equivalent to 130 kv. in so far as failure to ground was concerned. Certain of the joints tested have factors of safety to ground which are slightly lower than failure between phases, as this makes the best operating type of joint. The failure of No. 4 joint by puncture of the factory-formed insulator is the second case which has come to my attention; in the first one the workman did not understand the assembly of the material and the joint was poorly made with large voids existing in it. From the internal discharges reported on this test I judge that some similar phenomena occurred.

In discussing the last three types of joints tested it is well to emphasize the practical advantages in using a short-length joint where proper factors of safety can be obtained. It is evident, however, that the longer the joint the more reliable it will be in operation regardless of its type.

The method of accelerated-life testing is important in comparing results published by other authors. For instance, this is the first case which has come to my notice where thirty minutes per 10 kv. change has been used instead of increments of one hour for 10 kv. As there has been considerable doubt expressed in the past that even the one-hour increment gives proper comparative results for various types of joints, we believe that testing of this character should be longer and reduced voltage values used. Such a test method is more expensive but gives a better indication of the service results that are likely to be obtained.

The seventh joint of the so-called "curtain-roll" type is one with which we have had successful experience on a single-conductor 44-kv. installation. The joints are but 20 in. long, although the stresses are approximately the same as those tested by the authors on a 36-in. structure. This construction produces simple joints of uniform workmanship for round conductors, as long as they are straight, but it cannot be applied to sector conductors.

C. A. Adams: As yet we know practically nothing about the fundamental nature of dielectric phenomena. There are several hypotheses and much superficial misconception. As yet, we don't know even what are the significant variables with which we are concerned in this field. Moreover, much of the so-called "practical research work," which has been done bit by bit here and there without coordination is likely to be not only useless but in some cases actually misleading.

If manufacturers and users of insulated wires and cables and of other insulated apparatus would cooperate in a comprehensive research into the fundamental nature of dielectric phenomena at an expense to each which would be extremely modest as compared with the probable value of the results, there would be some hope of solving this most important problem. In such an undertaking, it would be necessary to enlist the assistance of the ablest physicists and chemists in the civilized world, but for work of this kind such assistance can be obtained at relatively small expense.

I have been endeavoring to start such a movement for the past seven years and a small start has been made by the organization of the Insulation Committee of the Engineering Division of the National Research Council, this Committee being also attached to the Research Committee of the A. I. E. E. But it is only recently that some of the users of cables are being forced to realize the need of such fundamental research.

L. A. Zima (by letter): The authors start out with an assumption of "Suitable Cable." This is a broad assumption to make for high-voltage cable, considering our limited operating experience to date. They further state that high-voltage cable jointing must receive considerable attention in the near future. Perhaps, from the manufacturer's standpoint, this is correct; but the cable user has given a great deal of attention to this problem ever since high-voltage cable has been manufactured, and has had reasonable success. This success is based on long practical experience following long tedious research work on experimental joints. Work along this line has been somewhat retarded waiting for the cable manufacturers to make suitable cable.

I rather question the three essential properties mentioned. Simplicity of design is certainly to be desired but it is not an essential property.

High dielectric strength is desirable but this does not necessarily mean very high instantaneous breakdown voltages or on short-life test. It is possible to make up a joint to give very high dielectric strength on instantaneous voltage application, but which will fail utterly to give satisfactory results in normal operation.

Dielectric loss. as low as that of the cable, is not an essential property of a cable joint. Due to the large radiating surface of the joint and the large volume of surrounding air in the manhole, the cable joint is at a much lower temperature than the cable inside the duct line.

The essential properties and requirements of a satisfactory cable joint are as follows:

a. Proper design, keeping the voltage gradient of all points in the joint within proper limits.

b. Materials of good quality, having high dielectric strength, with an specific induction capacity of relatively the same value as that of the cable. These should not vary in normal operation.

c. Workmanship of the highest order.

The voltage tests made on the various joints were of comparatively short duration, lower values and longer time would be more desirable and would more nearly approximate service conditions.

My attention is particularly directed to the electrical characteristics of Joint No. 4. Of the seven types of joints, the author finds this one to be the poorest of the lot as it has the lowest dielectric breakdown value. The reason for this, it seems to me, is not that of design but rather the general method of construction, especially of workmanship. The materials were not properly assembled and the filling probably faulty.

There are many of these joints in operation and they are giving satisfactory service. If properly assembled, using good material and with high-grade workmanship this joint will give a dielectric-breakdown test value, instantaneous and accelerative life, equal to that of the cable.

The Brooklyn Edison Company has had a large number of these joints in service over a year,—probably from 2500 to 3000, —and the operating results have been satisfactory. Refinements on these joints have continued, slight changes made in the construction, strengthening the weakest points, properly training the splicer for this type joint, and maintaining close supervision to insure high-grade workmanship.

A number of joints constructed with these refinements are now under test. The result of the first eight joints is as follows:

Tests on Joints in Sector Cable. These were three-conductor 350,000-cir. mil, sector cables with $20 \times 10/64$-in. paper insulation, $9/64$-in. lead. Tests were made with three-phase, 60-cycle voltage.

On all the joints except No. 1 the voltage was started at 70 kv. between phases and increased in 10-kv. steps remaining constant for one hour at each step. At 120 kv., voltage was held constant until breakdown occurred.

Joint No. 1 was subjected to 50 kv. for 405 hours before it was raised to 70 kv., after which the test was identical with those on the other joints.

Joint No.	Hours at 120 Kv.	Total Hours on Test
1	3.1	413.1
2	6.4	11.4
3	6.4	11.4
4	7.2	12.2
5	7.8	12.8
6	5.3	10.3
7	4.3	9.3
8	5.0	10.0

The failures occurred at 120,000 volts after a number of hours as shown. Examination showed the following:

Breakdown between conductors at sharp bend in conductor insulation near cable crotch.

Failure between conductors at porcelain spacer due to jamming and breaking conductor insulation.

Breakdown at edge of belt insulation due to sharp bend in conductor insulation.

A number of failures in cable crotch of the prepared cable ends.

These tests are a fair measure of the dielectric breakdown voltage values of the cable joint on a long-life test at comparatively high values.

As experience has demonstrated the value of long accelerated life tests to determine satisfactory cable, the same holds true for cable joints

I would recommend that a standard method of long accelerative life tests be set up so that a direct comparison can be made on joints and cable of different types of construction as made by various manufacturers or operating companies These tests should then be supplemented by simi ar tests, using d-c. voltage instead of a-c.

G. J. Crowdes: The work on joints, when completed, will comprise the construction and testing of about twenty joints. The following are results of tests on five more joints which may be of interest.

A duplicate of the varnished-cambric joint (see Fig. 3) was constructed with No. 00, 9 × 6/32 in. paper-insulated cable having round conductors. This joint had the same high loss characteristics as the previous varnished-cambric joint. The dielectric strength of this joint was quite high as shown by the following table:

3-Phase, 60-Cycle Kv.	Time (Min.)
92.5	60
110	30
120	30
130	30
140	28 to failure

The failure occurred between conductors about 4 in. from the edge of the belt. There was no evidence or charring or burning along the penciling.

Two joints were next built on 250,000 cir. mil. round-type cable with 9 × 6/32-in. of impregnated-paper insulation designed for 25 kv. working pressure. The construction of the joints was identical with the previous 25-kv. penciled paper joint (see Fig. 5) with two exceptions, (1) the length of penciling was increased to 2 in. and (2) each conductor was reinforced back to the crotch of the cable. One joint was filled with a standard hard filling compound and the other with petrolatum.

The loss in the joint with hard filling was considerably higher than the loss in the petrolatum-filled joint, at working voltage and a temperature of 80 deg. cent., the ratio being about 2 to 1. In dielectric strength there was practically no difference:

3-Phase, 60-Cycle Kv.	Hard filling Time (Min.)	Petrolatum filling Time (Min.)
92.5	60	60
110.0	30	30
120.0	30	30
130.0	30	30
140.0	30 failure	24 failure

The failure in both joints occurred at the edge of the belt insulation between conductors. There was no evidence of burning along the penciling.

The next two joints were constructed using 300,000 cir. mil. sector-type cable, with 9×6/32-in., impregnated-paper insulation. These joints were identical with the previous penciled paper joints described in the paper (see Fig. 3), with two exceptions, (1) the penciling was increased to 2 in. in length, and the built-up insulation was carried farther along the conductor for a distance of about 2 in. The conductors were not reinforced to the crotch. One joint contained hard filling compound and the other petrolatum.

Here again the joint with hard compound showed much higher loss characteristics. The slope of the loss curves with both voltage and temperature was considerably steeper in the hard-compound joint than in the petrolatum-filled one.

The dielectric strength of the hard-compound joint in this case was somewhat greater than the petrolatum joint as shown in the fo'lowing table:

3-Phase, 60-Cycle Kv.	Hard Filling Time (Min.)	Petrolatum Filling Time (Min.)
92.5	60	60
100.0	30	12 failure
120.0	30 failure	

The failures on both of these joints were between conductors at the end of the tape-on insulation. Severe burning was evident along the penciling in each case.

There is one striking fact evident from the tests on the last four joints and that is the difference in dielectric strength between the sector-type cable joints and the joints on round cable. The joint construction is identical except that there is no reinforcing on the sector-cable joints. Yet, on the round-type cable joints it was possible to reach a voltage of 140 kv. and hold this stress for considerable time. On the sector-cable joints, 120 kv. was reached on one joint and 110 kv. on the other. The failure on the sector-type joints followed the penciling.

It does not seem possible that the reinforcing of the conductor to the crotch (which was the only difference between the two types of joints) could account for the great difference in dielectric strength.

E. W. Davis: We quite agree with those who have discussed our paper, that dielectric-strength tests should be standardized, but we are not ready to accept such tests as the sole criterion for the value of an insulating material. Of all the electrical tests that we made on the various types of joint, we found that the dielectric-loss test was the most sensitive, and that it gave the most consistent and conclusive results. Experience has shown that a joint designed for normal dielectric strength and low dielectric loss will stand up better under severe operating conditions than one with high dielectric strength and high dielectric loss.

All the joints tested were opened and carefully examined and photographic records made of the paths of carbonization. A few of the joints were tested with radio apparatus installed in the ground circuit, and the tests stopped at the first signs of internal discharge. It was from a careful study of the paths of carbonization that the weak spots in the cable joints were found and the design changed so as to eliminate them as far as possible.

We have not discussed the question of workmanship in this paper. A poorly designed joint will not give satisfactory results, even though the workmanship is perfect. All of the joints tested were made by the same man so that the quality of workmanship was undoubtedly the same in all cases. In none of the joints that we opened and examined was it possible to say that the cause of the failure was due to poor workmanship.

Unfortunately, when the earlier work was done on the joints, we had only single-phase voltage available. Some of this work has been repeated with three-phase voltage with substantially the same results. Dielectric strength tests at high and low temperatures, show very little variation, especially if the results are comparative. The joints that show the higher dielectric strength at low temperatures, invariably have the higher dielectric strength at high temperatures.

We feel that the proper design of a joint to be put into a cable installation is well within the province of a cable manufacturer, but that the question of workmanship is a matter with which the operators should deal.

Discussion at Pacific Coast Convention

THE 60-CYCLE DISTRIBUTION SYSTEM OF THE COMMONWEALTH EDISON COMPANY[1]

(Kelley)

Seattle, Washington, September 17, 1925.

P. P. Ashworth: From a consideration of the line diagrams in this paper and in other papers presented, it would seem advisable for the Institute to adopt a set of standard symbols to be used by authors in these diagrams. This would make for clarity and simplicity. In Fig. 15 of Mr. Kelley's paper the key to symbols is not given, thus detracting materially from the value of the diagram.

I understand from Mr. Kelley's paper, that the 4000-volt neutral on each circuit is grounded at the substation only and is isolated from the neutrals of other circuits. May I ask if there is any particular advantage in this isolated-neutral system over an interconnected-neutral, frequently grounded? The latter system has the advantage of making possible the use of three-conductor cables and three-pole instead of four-pole switches, and with reasonably good balance in the phases, the load diversity on various circuits will keep the neutral current down to a low value.

Has the relaying system on the loop feeders functioned properly under all conditions?

It is noted that three-phase transformers are used in some of the substations. Have these proved to be as reliable as single-phase transformers under like conditions?

What type of secondary distribution system is used? Are secondaries of adjacent substation paralleled? If so, what type of sectionalizing devices are used?

Referring to Fig. 15, assume the equipment supplying circuit No. 2 is out of commission; do the equipment and cables for circuit No. 1, say, have sufficient excess capacity to carry all of the load on circuit No. 2, or must this load be divided, with part on No. 1, part on No. 3, etc.? If the latter is the practise, then it would seem that a rather extended interruption would be given customers on some branches, due to the necessity of the service men going to so many tie points to transfer the load.

Without experience in the matter, it appears to me that the method used, of picking up and transferring the load by means of disconnecting potheads, is not entirely safe. Possibly there are suitable safeguards not mentioned in the paper, and I should like Mr. Kelley to give further information and experience on this point.

Fig. 20 suggests a point that is worthy of more serious consideration on the part of distribution engineers, namely, that the installed transformer capacity is on most of our systems greatly in excess (often two to four times) of the maximum loads which the transformers may safely carry, and the transformer losses are therefore more than they should be. Diversity and nature of loads, anticipated growth of loads, etc., make the economical solution difficult to evaluate; nevertheless, intensive work on our part should lead to an enormous aggregate reduction in energy losses and in transformer investments.

Also in connection with Fig. 20, it is noted that curves 1, 2 and 3 discussed in the text are not so designated on the figure.

Without presuming to attempt to solve the problem of the necessary modifications in the Chicago system to take care of load growth, may I suggest that there is no fundamental reason why 12,000-volt overhead circuits cannot be as successfully installed, operated and maintained as 4000-volt overhead circuits. Changes in present construction and maintenance methods may be necessary, new types of tools developed, and even existing municipal ordinances modified, but these are not likely to prove impossible obstacles to overcome. The engineer is not usually justified in "taking anything for granted," especially, the seemingly impossible.

The important facts that (1) generation in Chicago is at 12,000 volts, eliminating the necessity for substation transformers, and (2) so far as voltage regulation is concerned, a 12,000-volt, overhead circuit has approximately nine times the capacity of the same circuit operated at 4000 volts, would, it appears to me, justify a very serious consideration of changing to 12,000-volt Y distribution, with overhead circuits, where the 4000-volt circuits are or could be overhead. Standard 6900-volt transformers could be used. A progressive development program might be carried out involving the change of the most heavily loaded existing circuits to 12,000 volts using the 4000-volt equipment released, including 12,000/4000-volt transformers, in the outlying, lightly loaded districts. Ultimately higher voltage loops, say 44-kv. or 66-kv. from the generating stations, will likely be necessary.

R. J. C. Wood: One of the big difficulties in getting the power away from the terminal substations on the 220-kv. system will be to get sufficient circuits away at 60,000 volts; therefore, we are beginning to become interested in 60,000-volt cable.

Personally I am not able to tell anything about experience with 60,000-volt cable because we have not had any; but I hope to stimulate somebody else here into giving us a little information about high-voltage cable operation.

E. E. Campbell (by letter): In connection with the remote-control substations of the Commonwealth Edison system, a few facts and figures may be of general interest. These stations are usually designed to house seven circuits, and are enlarged when necessary to take care of five more circuits. Comparative figures for attended and remote-control substations on January 1st, 1925 show the following distribution of load and of circuits:

1. A. I. E. E. Journal, November, 1925, p. 1189.

	Attended Substation	Remote Control Substation
Maximum load on any one substation	1500 kv-a.	6100 kv-a.
Average load per sub	9350 kv-a.	3800 kv-a.
Maximum number of circuits in any one sub	20	7
Average number of circuits per sub	11.2	4.8

A few interesting figures regarding the nature of the load connected to the 60-cycle circuits have recently been prepared. These figures indicate that:

62 per cent of all the circuits have a maximum load at night, with an annual load factor of 27 per cent.

27 per cent of all the circuits have a maximum load during the day—*i. e.*, power load—with a load factor of 42 per cent.

11 per cent of all the circuits have a day and a night maximum which are approximately equal with a load factor of 54 per cent.

The latter condition sometimes results in a 5:00-p. m. maximum load on the circuit. In this case, however, the peak is of short duration, and for that reason can be carried with safety even though it exceeds the normal rating of the cable and other circuit equipment.

The possible future omission of induction regulators is something to be hoped for. A great deal of the complication in a substation is due to regulating the voltage of circuits. Final abandonment of individual circuit regulation will probably come in two or three steps, first by substitution of 5 per cent regulators for 10 per cent, and then probably regulation of the substation bus. Since the remote-control substations receive transmission feed from operated stations, the pressure at the remote-control substation will not be as good as at the operated substation, because of the 1.2-ohm reactor in the line between the two substations. The poorer regulation will probably make it necessary to retain some regulation in the remote-control substations, especially where the power factor is low.

The circuits, which have a maximum rating of 200 amperes, are loaded on the average to about 135 amperes. This loading is necessary in order to have capacity to carry load of other circuits in case of loss of a feeder, and to provide reserve capacity so that reasonable increments of load can be taken on without waiting for the installation of additional circuit capacity.

ENGINEERING AND ECONOMIC FEATURES OF DISTRIBUTION SYSTEMS SUPPLYING INCREASING LOAD DENSITIES[1]

(Applegate and Brenton)

Seattle, Washington, September 18, 1925

A. H. Kehoe (communicated after adjournment): The formulas submitted to obtain the economical design of transformer spacing, transformer size and secondary conductor size, are based on a uniform density of load and a reasonable number of service points. These conditions are seldom even approximated in practise. The calculations assumed that the location of the transformers is such that the center of distribution of the particular load will be chosen. The fact usually ignored in such calculations is that any concentrated load equal to more than one-half of all the load being considered causes the electrical center of distribution to occur at the point of concentrated load. In practical distribution the majority of transformer locations will be at the concentrated loads and such an arrangement makes it uneconomical to space many of the distribution transformers at regular junction points on the mains. However, it allows a larger average size of distribution transformer and a smaller secondary conductor to be used than is possible with the same amount of load distributed uniformly over the territory. This condition also requires several different sizes of transformers to be used on the same system. It is fortunate that any proper secondary distribution-system costs for varying loads gives a flat "U" curve, as this, with concentrated loads mentioned above, makes it possible to use a small conductor and yet be able to add large future loads as they occur without having to change the mains.

1. A. I. E. E. Journal, September, 1925, p. 937.

H. Goodwin, Jr. (communicated after adjournment): Fig. 7 shows, diagrammatically, the distribution transformer connections for supplying three-phase, three-wire power secondary from 2300/4000-volt, four-wire primary. This indicates a star connection of the primary, and delta connection of the secondaries, the center point of the star being connected to the neutral wire of the primary system.

The connection of the neutral to the center point of the star is not usual practise and has been found by test to be very unsatisfactory. The reason is that, with this connection, the transformer bank tries to balance the voltage on the primary phases. It is practically impossible to keep the three-phase voltages balanced and moreover, with single-phase regulators and lighting distribution from the same feeder, it is usually desired to have the voltages slightly unbalanced in order to give better light regulation.

Any voltage unbalance in the primaries sets up a circulating current in the transformer bank, tending to balance the voltages on the three phases. This can readily overload the transformers and, in any event, constitutes a useless loss. Also, this balancing tends to destroy the effect of single-phase regulation which it is desired to obtain with the four-wire, three-phase system for combined lighting and power distribution.

The figure really should be altered so that it may not lead others astray.

At least one company has made the neutral connection through a primary cut-out from which the plug was removed. The purpose of this was to provide a means of giving temporary service from an open-delta arrangement should one of the transformers fail. However, I understand that they have not had occasion to use it, and have decided to abandon the complication and chance for accidental incorrect connection.

Walter Brenton: The points brought out by Mr. H. Goodwin, Jr., are very well taken. It is realized that the grounded-star neutral for primary power connections is not satisfactory or desirable under many circumstances. This method of connection, however, is standard practise with some companies, as shown by Mr. Hinson in the *Journal of Electricity* for June 1, 1924. If a fault should occur in one of the transformers, the other two would continue to carry the load on open delta.

THE RADIO INTERFERENCE PROBLEM AND THE POWER COMPANY[1]

(Corbett)

Seattle, Washington, September 18, 1925

H. P. Miller, Jr.: The electric power industry is to be congratulated on the results obtained in studying the problem of interference with radio broadcasting and reception. The fact that this study was not required for the proper delivery of electric power shows how much the electric light and power companies have the interest of their respective communities at heart.

Mr. Corbett has touched on the sources of interference due to high-frequency, continuous waves and states that little of this is attributable to the light and power companies. I should like, however, to point out an interesting case in which a power company innocently assists in distributing this type of interference over a fairly broad area.

The Federal Telegraph Company furnishes communication by radio telegraph on a commercial basis along the Pacific Coast between Portland, San Francisco and Los Angeles. Three duplex communication circuits are in use between Portland and San Francisco and three between San Francisco and Los Angeles. The transmitting station at San Francisco is located on the San Francisco Bay about two miles east of Palo Alto. Six arc transmitters are used simultaneously, being connected to six antennas arranged in umbrella fashion about one 626-ft., guyed steel mast.

1. A. I. E. E. Journal, October, 1925, p. 1057.

In designing this station, the main consideration (outside of interaction between the transmitters) was to eliminate the spacing wave and prevent harmonic radiations. The results desired at that time were obtained by means of the so-called nodal-point circuit. Without going into detail, this circuit confines any harmonics or parasitic emissions to a local non-radiating circuit. The main transmitting wave is also kept in this circuit during spaces between dots and dashes of the telegraph code. The spacing wave is therefore eliminated and any harmonics of the transmitting wave are confined to a local circuit.

No complaints of interference to broadcast reception were received until a little less than a year ago, when broadcasting on wave lengths below 300 meters was started. It should be remembered that continuous waves at that frequency cannot be heard in a receiver unless thay are heterodyned to produce an audio-beat frequency. They would, therefore, be unnoticed unless the receiver were oscillating or unless the weak signals of a distant broadcasting station were at almost the same wave length. A strong signal from a nearby station will usually drown out the interference.

An investigation showed that harmonics below 300 meters were weaker than at higher wave lengths but, on account of their better radiating properties, were harder to confine to non-radiating circuits and hence were picked up more readily on a nearby receiver. Practically no harmonics were being radiated from the antennas and only two or three were at all prominent in the local circuits. In spite of this it was possible to pick up in Palo Alto with an oscillating receiver, harmonics over the entire lower portion of the broadcast range. Most of the harmonics were extremely weak and would not be noticed when listening for broadcast transmissions. It was found that these harmonic radiations were being guided into Palo Alto by power lines. The line supplying the station does not go near Palo Alto, but a line very closely coupled to it does, so that practically a continuous conductor is furnished from the station to Palo Alto. The manner in which the harmonic currents get into the power line has not been definitely determined but they appear to be conducted from the station by a buried lead-covered cable, and to pass through the transformers supplying the station.

These results are very similar to some obtained at the Leafield Arc Transmitting Station[2] in England. There, inductively coupled circuits were used to keep harmonics out of the antenna and the entire primary circuit was shielded to prevent local interference. In spite of these precautions, interference was still heard in a town six miles away. An investigation showed that this interference was being carried over the telephone lines. Choke coils were accordingly placed in both ends of the line and the trouble was eliminated.

The solution of a problem of this type, therefore, requires the cooperation of the power company and the radio company. Both can carry on their business—in one case delivering kw-hr. and in the other delivering messages,—whether the interference is eliminated or not but they must both consider the broadcast listener.

No doubt the power company has received relatively few complaints from around Palo Alto. The radio fans are aware of the presence of the arc-transmitting station and the major part of the interference noted is attributed to that source. The fact that 50 per cent of the complaints received are reported for periods when the station is shut down shows the injustice of this attitude. Few of the fans realize how much they have benefited by the development of the nodal-point circuit or that if the old, and now becoming obsolete, arc circuits were in use, reception around Palo Alto would be almost impossible. The Federal Telegraph Company has not been satisfied with stopping at the nodal-point circuit but has made further studies to determine the sources of harmonic radiations. It appears entirely possible to cut down these radiations to very low values but even this is not enough if a wire transmission system is available for distributing them over the neighborhood.

2. "The Leafield Coupled Arc," Major A. G. Lee and H. A. Gill, *Journal Institution of Electrical Engineers*, July 1925.

H. M. Trueblood: Mr. Corbett's paper impresses me as being an excellent survey and my comments are not intended in any spirit of adverse criticism.

Mr. Corbett discusses briefly the question of radio interference from telephone ringers. He says, "Telephone ringers," (by which I assume he means telephone ringing machines) "have been common sources of trouble to the radio listener."

I have no statistics on this question, but I feel entirely safe in saying that the amount of trouble with broadcast reception due to telephone sources,—and most of it has come from ringing machines,—has been quite small compared with that due to other sources. It has been a localized condition, confined very largely to regions immediately surrounding the smaller central offices, where the vibrating-contact type of interrupter is used. The matter has been fully and carefully investigated, and simple but adequate means have been developed, consisting chiefly of air-core coils and condensers which are effective in preventing this interference. Information on the subject has been transmitted to all the associated companies of the Bell System, and most of these companies are now operating on the basis of applying these preventive measures as regular equipment to this type of ringing machine, in order to forestall trouble of this sort.

After referring to the devices I have just mentioned for application to telephone ringing machines, Mr. Corbett observes that these means have not been applied to communication lines which have picked up the interfering waves by induction. It seems to me that we can hardly expect the telephone companies to assume responsibility for the elimination of interference when the disturbance is merely picked up by their lines and they are not primarily responsible. This would be like asking a power company to suppress radio interference which arises from an electric iron or some other appliance connected to its circuit.

In the same place it is stated that "the audio frequency hum of a power line is functional and no remedial measures are practicable." Of course Mr. Corbett's attention here and elsewhere in this paper is focussed on the problem of interference with broadcast reception, and we must not misunderstand him as meaning this statement in the broadest sense. We all know that there are things which one can do to a power line to reduce the audio-frequency waves that exist upon it. This is done very commonly in connection with problems in inductive coordination.

My remaining point refers to the description of a method of locating a defective joint by means of a condenser, where it is stated that "at a faulty tap, a loud indication may be heard on the tap line and on the main line toward the source of power, but on the main line beyond the tap, where the current is not affected by the poor contact, much less noise will be heard." It seems to me that, in a case of this kind, the contact itself being the source of the disturbance, one would expect that the energy would spread out in all directions more or less equally, and I should be glad if the author would explain a little further what he has in mind here.

R. B. Ashbrook: For the past year and a half, the Southern California Edison Company has had two men almost constantly in the field for the purpose of investigating complaints of interference to radio reception, so that we may come to some conclusion as to how we may cope with the situation.

It was generally conceded at first that it was placing a serious obligation on the power companies to investigate and attempt to remedy trouble that presented itself only in the form of interference to radio reception. However, we have later come to the conclusion that our response to complaints and cooperation with the public, has not only been beneficial as a "good will" proposition, but, in many occasions, represented a material saving to the company in locating and remedying trouble before it had become serious and resulted in actual damage.

The methods of locating the source of these disturbances are far from satisfactory, while those used by this company are substantially the same as outlined by Mr. Corbett. There is considerable room for improvement before the average trouble-man can effectively handle this class of trouble.

We, too, have found that the use of the loop as a direction finder for the exact location of the source of disturbance is not dependable, but the directional properties and convenience of the loop, together with the audibility meter, are quite indispensable in this class of work. It has been our experience that considerable advantage is derived from providing the set with instruments for maintaining the amplification at a constant value throughout the investigation.

It has been necessary, in some cases, to take a series of readings at regular intervals and plot a curve as well as make a careful study of conditions in the field before a definite conclusion may be reached as to the source of the disturbance.

When conditions permit, we have found it advantageous to assume that a given disturbance creates a field in all directions within a short radius from its source, although a large proportion is propagated a great distance over the power circuits similar to "carrier current." With this assumption the loop is placed at right angles to the line and the amplification, adjusted to a value so that the disturbance is just audible. A survey is then made with the loop in this relation to the line and when the observer comes within the field of the disturbance a material increase is noticeable. Readings are also taken at intervals with the loop parallel with the line, to determine whether the observer is approaching or working away from the source of disturbance. Circuits or taps, leaving the line, must be taken into consideration.

Our experience has been that the greater percentage of the interference is caused by our 10-kv. and 15-kv. distribution lines. These circuits usually form an extensive network and are arranged with switching facilities for inter-connection of circuits, consequently employing a great number of pole-top switches, which, as Mr. Corbett points out, is a source of numerous causes of interference. We have noted that the trouble is not always located in the electrical features of the switch, but often if the bearings of the switch fit loosely, a static discharge takes place between the cross bar to which the insulators and blades are fastened and the remaining hardware.

Other cases frequently found in distribution lines of this class are poor connections in fuse clips, causing small arcs; loose ground connections; cracked transformer bushings; punctured windings, causing static discharge to core or secondary, the primaries usually being ungrounded. One case in particular, which may have resulted more seriously than in interference to radio, was the finding of a transformer that had broken down between primary and secondary. The secondary was grounded at the transformer pole, but, due to the sandy nature of the soil, this constituted a poor ground. This placed the secondary at primary potential to ground, which was a dangerous condition, as this transformer served power for the operation of a pumping plant and for domestic lighting service.

Another case that paid well for investigating was traced and located some nine miles from the complaint. The disturbance originated in one of the generators of a hydroelectric plant and further investigation revealed that the insulation of the machine was defective, a continual discharge taking place to ground. As the machine was connected directly with a distant substation by an ungrounded line, the failure of the line would have resulted, probably, in serious damage to the machine.

Very little interference has been experienced with lines on steel towers with the exception of a few cases of defective insulators and poor clamp connections. We believe this is due to the fact that all parts of the tower and hardware are effectively tied together, thus offering no opportunity for static discharge. We have experienced numerous disturbances arising from insufficient bonding of hardware of 60-kv. circuits on wood poles; particularly the bonding of metal cross arms with the old-style, lapped metal strips. Exposure to weather has loosened the nails and allowed the strips to separate, causing a static discharge which, we believe, has in some instances been the cause of poletop fires.

It is indeed a difficult problem to investigate all the complaints of radio interference but it is our belief that with better methods and suitable equipment the local trouble-men will soon be in a position to take care of the majority of the new cases. With this end in view at the present time all cases of interference are handled by the engineering department for the purpose of study and research.

G. H. Smith: Mr. Corbett has tagged some radio troubles, that we hadn't yet found, to add to the questionnaire we give to radio fans who complain that our "transformer is leaking." I might say we have had one man busy for some time finding and remedying radio interferences. We find that there is enough trouble traceable to our system to make it worth our while to investigate every complaint, whether it comes from one of our customers or not. The good will we gain by it, we feel, pays us to look into the complaints and remedy them.

We make up a questionnaire with forty or fifty points which we ask the customer to answer while he is waiting for the trouble-man to investigate.

The man who searches for the trouble uses a loop and a six-tube set and has been able to find everything without much delay except trouble from series arc circuits. A poor contact in the base of a lamp, or a cutout that is not operating right, will radiate five miles in each direction, and the loop will lead one in circles of from a block to a mile in diameter. We find it almost impossible to find the trouble in such a case. There is one such spot that has been on our system for eighteen months, and I am not sure that we have found it yet.

W. R. G. Baker (by letter): The fact that there are such a multitude of devices which are potential sources of interference, and that these devices are the products of a large number of manufacturers, tends to complicate any remedial action that might be suggested. This applies particularly to electrical devices used in the home. Unless these devices are made radio-interference-proof, complaints may increase rather than decrease.

To apply corrective measures to all the interfering units now in use in homes is practically impossible. Fortunately such extreme action does not appear necessary, since the public is beginning to recognize the various sources of interference, and to correct the defect, discontinue the use of the device, or limit its use to periods when the disturbance is not objectionable.

While this condition holds for devices already purchased, a very different attitude will be taken when purchasing new equipment. Already the public is beginning to ask when purchasing equipment, "Will this cause radio interference?" and it behooves the manufacturer to be able to state that his products are interference-proof.

L. J. Corbett: This paper, long as it is, is compulsorily brief. For that reason it is quite possible that it is too brief in certain places and subject to misconception.

One of these points was taken up by a representative of the Federal Telegraph Company, who mentioned a case at Palo Alto. A company of its standing, presumably maintains its equipment in first-class order. In mentioning the faults of the radio industry, I had more particularly in mind the smaller companies, the government stations to a certain extent, and ship and shore stations mentioned, which are far more at fault than large commercial organizations like the Federal Telegraph Company. The case mentioned at Palo Alto may very possibly be one of those instances of some disturbance whose exact nature was not determined, causing resonance in a primary circuit and carrying a sustained frequency over it for a considerable distance.

Dr. Trueblood called attention to a slight error in the use of the term, "telephone ringer." Evidently I did not use the proper technical term in calling them roughly as a class, "telephone ringers" so I accept the correction. It is realized also that the ringers in ringing machines in small offices are the ones at fault. I did not amplify my statements enough to make this clear and I am glad that Dr. Trueblood has done this for me.

Dr. Trueblood also questioned the completeness of my statement that the suppression of the 60-cycle hum was "impracticable." I did not mean "impossible." When we consider a system like our own, for example, with 31 power plants and 200 primary substations, the suppression of the third harmonic

or residual currents throughout that system, to the extent necessary to keep them from affecting radio apparatus, is what we consider not practicable.

Reference was made to the equipment developed in San Jose. As I mentioned in abstracting the paper, we are not so sanguine of the results now as when I wrote that statement. However, the theory of it is this: Suppose, at a tap, we are taking off a load current of 5 amperes. If on the main line a current of 10 amperes is going on past the joint, the wire toward the source will be carrying 15 amperes. If the joint is imperfect, there will be some arcing occurring at that joint. The 5-ampere current going off to the load and the 15-ampere current from the station will contain ripples. The 10-ampere current, going on beyond that tap, however, will be comparatively smooth although of course the wires will give off some of the emanations arising from the arc.

The thought in the paper is that the emanations beyond the tap from the wire carrying the smooth current would not be so strong as those from the wires carrying pulsating current. We think this type of equipment has possibilities but we are not yet satisfied, and if I were writing the paper again, I would not write so confidently in regard to this feature.

STORED MECHANICAL ENERGY IN TRANSMISSION SYSTEMS[1]

(Jollyman)

Seattle, Washington, September 15, 1925

R. J. C. Wood: The outstanding point which struck me in this paper was the very small number of kilowatt-hours that are stored in the kinetic energy of the moving fly-wheel. Here is a 27,000-kv-a. unit and the total stored energy from full speed down to nothing is only 16 kw-hr. That seems to be such a small amount that it would not enter materially into any disturbances of the system, particularly, as the whole of that 16 kw-hr. is not used since the speed will not drop from full speed to zero; the fluctuation will be very small and the amount of energy released will correspond to it.

L. N. Robinson: In connection with Mr. Jollyman's paper, it may be of interest to mention that it is intended to synchronize the 19,500-kv-a., hydraulic-turbine-driven generators at the Baker River Station automatically.

It is expected that this will facilitate operation and improve the service considerably. It will reduce the number of attendants to one on each shift. It is expected that automatic synchronizing will expedite the starting up and connecting of generators to meet changing load requirements and that it will be effective in restoring service quickly after serious interruptions.

Two speed switches are geared to the shaft of each of the generating units. One speed switch is closed when the speed of the unit is more than 95 per cent of normal speed and the other is closed when the speed is less than 105 per cent. The two speed switches are connected in series so that the circuit is closed only when the speed of the unit is within 5 per cent of normal. When he desires a unit to be synchronized automatically, the operator will turn a key switch on the main switchboard. This key switch connects the closing circuit of the generator oil circuit breaker through the speed switches and the oil circuit breaker will be closed automatically when the speed comes to within 5 per cent of normal. This procedure applies whether the machine is being started up or is coming back to normal after excessive speed due to sudden interruption of the load.

The generators are equipped with amortisseur windings, since they are intended to be thrown on the bus without d-c. field excitation, relying upon the induction-motor effect of the squirrel-cage winding to bring them nearly to synchronism. The automatic synchronizing control is interlocked with the generator field switches so that a generator cannot be thrown on the bus automatically unless its field switches are open.

As far as we know, these are the largest generating units to be equipped for automatic synchronizing up to this time, and they are of especial interest because each unit constitutes approximately 20 per cent of the present peak generating capacity of the system on which they are being installed.

J. P. Jollyman: While as Mr. Wood has pointed out, it is true that the fly-wheel effect of a large generator is only a few kilowatt-hours, still the total fly-wheel effect of a large system is sufficient to prevent the usual load changes from producing material speed changes within the time required for governor action.

1. A. I. E. E. Journal, September, 1925, p. 948.

THE LONG SPAN ACROSS THE NARROWS AT TACOMA[1]

(Gongwer and Darland)

Seattle, Washington, September 15, 1925

G. S. Smith: I should like to ask Messrs. Gongwer and Darland if any provisions are being made to obtain data on the cable movement over the two main supports? This could easily be accomplished by means of a graphic instrument to keep a record of the sheave movement, together with temperature. A record of the wind velocity and its direction, as well as a log of ice loading or other unusual conditions, would be very desirable.

The slow movement of the cable over the supports due to the temperature or loading changes, as well as the vibrations which may take place, would make a very interesting study in this unusually long span.

Such data would be highly instructive from the standpoint of investigation and future design, and might also prove valuable from the standpoint of maintenance.

G. R. F. Nuttall: I should like to bring up a point in connection with cables for long crossings. In our own transmission lines we have had to go into the details of sag calculations and in all cases it is necessary to make quite a number of assumptions to start with, particularly in connection with cables which are formed of two different metals, aluminum and steel for instance, where the combined modulus of elasticity and coefficient of expansion of the two metals has to be taken into account.

Have any of the cable manufacturers made any experiments with cables having a layer of aluminum strands on the outside, then a layer of strands—the modulus of elasticity and coefficient of expansion of which lie between those of aluminum and steel—and within the center the usual steel core? This would offer a more homogeneous cable in which the relative movement between layers would be less likely to occur.

R. J. C. Wood: For our use we have developed a dynamometer which is essentially a steel rod some 20 in. long, and we measure the extension of that rod under load with an ordinary dial extensometer.

L. J. Corbett: In this paper the point which I noticed particularly was the test of the two types of cable—that with the concentric layers oppositely wound and that with the layers wound in the same direction. The Pacific Gas and Electric Company long ago adopted for Carquinez the cable in which the layers are wound in the same direction, with the idea of getting greater strength for a given weight. This method produces a very compact strand, and this was the controlling feature in the selection of the cable. A new point is brought up when tests showed a difference of 60 per cent in resistance. This is certainly well worth considering.

A. F. Darland: Mr. Smith has brought up the point of keeping a record of the movement of the cable over the sheave on the Narrows crossing. We have computed the probable movement we shall get, and expect probably a foot. No definite means has been provided at this time to keep a record of that movement, but it will undoubtedly be noted and recorded. We have a calibrated spring on each string of the high-tension insulators whereby we may know the tension in the cable, and we shall in addition keep an accurate record of the sag, measuring it with a level.

1. A. I. E. E. Journal, December, 1925, p. 1296.

Synopses of Several Papers Presented During 1925

Complete Copies Available in Pamphlet Form

TRANSMISSION LINE DESIGN

Mechanical Design of Spans with Supports at Unequal Elevations

G. S. Smith[1]
Associate, A. I. E. E.

The purpose of this paper is to derive a practical method of design, based upon the catenary formulas for spans whose supports are not at the same elevation. Furthermore, it is intended completely to formulate the method for applying it to any cable which is suspended freely or is uniformly loaded, as well as for obtaining its characteristics after the temperature or loading conditions of the cable have changed. This is a companion method to that presented before the Institute in 1917 by Professor F. K. Kirsten. Since certain changes in Professor Kirsten's original method seemed advisable to assure greater accuracy as well as to simplify calculations, these changed methods have been used in obtaining certain preliminary data needed for the method presented here.

After a brief survey of the present need for more accurate methods of mechanical design of transmission line cables, the several formulas which are adapted to spans with supports at unequal elevations, are given, and the method of using them is fully explained. All such special formulas are fully derived in the appendix.

The first method given depends somewhat upon interpolated values from the symmetrical span data. A second pure interpolation method is next described, which has the advantage of being shorter than the first, as well as more accurate, since it depends upon fewer interpolated values from mathematical tables.

A means of obtaining the maximum deflection of the cable from the straight line between supports is also explained. The investigation determining the exact position in the span of this maximum deflection proves of unusual interest.

The use of these two methods is then fully illustrated by the solution of three typical spans. Data for the cable used in symmetrical spans are first given, and from these the solution for the span with supports at unequal elevation is obtained. For the purpose of comparison the computations used in obtaining the desired values by each method are given in full for one of the spans chosen.

These data are entered on a complete set of forms stating all formulas used and indicating by the headings of each column, the operation performed to obtain the results recorded therein. These forms have been so arranged that by supplying the proper constants, they may be applied to any similar span problem, and thus will greatly reduce the work and the possibility of errors in the final results.

This affords a well defined method of making, to any desired degree of accuracy, computations which can be applied equally well to all types of spans with supports at any relative elevation.

1. Instructor in Elec. Eng., University of Washington.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

Complete copies to members on request free of charge.

ELECTRIC PROPULSION OF SHIPS

By H. Franklin Harvey, Jr.[1] and W. E. Thau[2]
Associate, A. I. E. E. Member, A. I. E. E.

The paper, of which the following is a brief summary, was presented at the Convention of the A. I. E. E. in St. Louis on May 13-17, 1925.

After a resumé of the older types of propulsion machinery, this paper discusses at length the application of electric drive to practically all classes of vessels.

The merits of electric drive as compared with mechanical transmission of power are treated from the standpoint of reliability, economy, weight, space, first cost, maintenance, operating expense and performance.

The outstanding characteristics of electric drive as set forth in this paper are: (a) Reliability equivalent to the reciprocating engine with better efficiency and with less weight and space. (b) Space requirements and weight comparable to direct turbine drive with better efficiency due to the fact that both prime mover and propeller operate at their favorable speeds. (c) Economy comparable to that of geared turbine drive with greater reliability and less maintenance cost. (d) Performance and freedom from interruption of service superior to any other type of drive due to the inherent qualities of electrical machinery and the fact that a casualty to any one unit has relatively little effect on the ability of the vessel to proceed. (e) First cost, admittedly, somewhat greater than some other types of drive offset by natural advantages possessed by no other type. (f) Safety superior to any other type of drive due to better maneuvering ability and multiplicity of units.

The relative advantages of turbine-electric and Diesel-electric drive, and the type of vessel for which each is best suited is also fully discussed.

1. Electrical Engineer, Newport News Shipbuilding and Dry Dock Company.

2. Marine Engineer, Westinghouse Electric and Manufacturing Company.

Presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

Due to the fact that Diesel engines are available only in comparatively low speed units, turbine-electric drive is best suited to vessels requiring large power, such as battleships and passenger vessels of the trans-atlantic type. The inherently higher speeds of turbines permit the direct connected generators, which, in the larger powers, are of the a-c. type, to be much smaller than could be used with direct-connected Diesel engines. Diesel-electric drive is peculiarly suited to lake and river vessels, tugs, ferry-boats and to small moderate sized coast-wise and ocean-going cargo boats.

The paper concludes with descriptions of specific installations, adequately illustrated by photographs and wiring diagrams, for such diverse types of vessels as yachts, tug boats, ferry-boats, cargo boats, dredges, and tankers. A brief description of the installation on several naval vessels is also included.

A list is appended of all electric driven vessels up to and including the year 1924, and also a very complete bibliography.

POWER DISTRIBUTION AND TELEPHONE CIRCUITS

Inductive and Physical Relations

H. M. Trueblood[1] and D. I. Cone[2]
Associate, A. I. E. E. Member, A. I. E. E.

Consideration of the relations between power distribution and telephone systems is naturally involved in any comprehensive review of the problems of the rapidly expanding power-distribution networks in this country.

Avoidance of contact and provision of suitable working conditions for employes in situations of close proximity are dealt with in the National Electrical Safety Code and in State Regulations, which provide arrangements for safety where complete separation is not feasible.

Heretofore, induction from distribution circuits has had less general attention than induction from power-transmission lines. Recently the Joint General Committee of the National Electric Light Association and the Bell Telephone System has undertaken comprehensive investigations of these problems. The study of induction under joint use conditions, now progressing actively at Minneapolis, is of particular interest. Pending completion of this and other studies, a preliminary and qualitative discussion is given.

Situations of exposure fall into three groups determined by the character of the area served. (1) "downtown" districts; (2) residential urban districts; (3) rural districts. The major problems arise in the second group. A wide variety of arrangements characterize both systems, and require consideration.

Among technical features, coefficients of induction for close exposures, shielding action of metallic cable sheaths for both power and telephone circuits, and "ground potential" effects, are distinctive problems. Where both classes of circuits are in cable with suitable precautions as to grounding, interference is rarely to be anticipated.

Low-frequency induction due to transient power-system disturbances is rare at the lower voltages but may assume great importance with higher voltage circuits, unless the amount of exposure or the fault currents are suitably limited. Various methods for reduction of disturbing effects are discussed.

Noise induction from power-distribution circuits is chiefly from residuals, which occur on single-phase branches of polyphase circuits, or where triple harmonics or load-current unbalances are introduced by grounding neutrals, or where admittances to ground of phase wires are unequal. Residual currents are largest in systems having multiple-grounded neutrals, both load currents and triple harmonics occurring. Approximate resonance at triple harmonic frequencies between the inductance of station apparatus and power cable capacitance has characterized several situations. Various single, two and three-phase arrangements are compared from the induction standpoint.

The closely related matter of unbalances in the telephone plant is briefly discussed. This is one of the subjects on the joint research program.

While the well-organized scheme of joint study and research referred to above should result in the development of technical information of general applicability, the solution of existing interference problems is attainable only by careful analysis of each actual situation. Here, and also in the construction of new plant for both services, it is essential that foresight be exercised to insure successful coordination in the period of great growth that is anticipated.

1. Department of Development and Research, Am. Tel. & Tel. Co., New York, N. Y.

2. Protection Engineer, The Pacific Tel. & Tel. Co., San Francisco, California.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

TRANSFORMER HARMONICS AND THEIR DISTRIBUTION

By O. G. C. Dahl[1]
Associate, A. I. E. E.

This paper discusses briefly the distribution of harmonics in single-phase transformers and in three-phase banks of single-phase transformers. Two winding transformers or three-winding transformers, where the harmonic current exists in two of the windings only, are considered.

Formulas for the distribution of harmonic currents between primary and secondary circuits are given.

Data and results from tests on small experimental

1. Massachusetts Institute of Technology.

Presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

transformers in the Research Laboratories of the Electrical Engineering Department, Massachusetts Institute of Technology, and also from field tests on a bank of power transformers and a transmission line, have been reproduced.

Both in laboratory and field tests, calculated and measured values check to engineering accuracy.

INVESTIGATION OF HIGH-TENSION CABLE JOINTS*

E. W. DAVIS[1] and G. J. CROWDES[1]
Member, A. I. E. E. Associate, A. I. E. E.

With suitable cable, the successful operation of a high-tension cable system depends on the joints between consecutive lengths and this phase of high voltage cable installation must receive considerable attention in the near future.

The essential properties of a good cable joint are:

1. Simplicity of design.
2. High dielectric strength.
3. Low dielectric loss.

The dielectric strength of a joint, assuming proper care and method in assembly, depends upon the materials used. It does not necessarily follow that a joint with high dielectric strength will have low dielectric loss. Low dielectric loss is essential because of the high thermal resistance of the joint.

Data is given from experimental tests carried out on seven different types of joints, four with 25,000 volt cable, and three with 33,000 volt cable.

The joints were made up in the center of a ten foot piece of cable and dielectric loss tests made at various temperatures and voltages. Knowing the loss of the cable itself, it was possible to determine the actual loss in the joint. In no case was this loss found to be lower than the loss of an equal length of cable.

The sample of cable with the joint in the center was then tested with high potential at room temperature.

COAL MINE ELECTRIFICATION†

W. C. ADAMS[2]
Member, A. I. E. E.

The conditions vary so greatly at the different mines that it is impossible to thoroughly cover this subject by discussions as to the many problems to be solved under varying conditions. This paper includes a brief discussion of some of the important problems of coal-mine electrification with descriptions of some concrete installations.

To purchase or generate power for mine requirements is determined on basis of minimum power charge against coal production. Alternating-current transmission results in better efficiencies and lower costs. The choice of coal hoisting systems is based on reliability with cost secondary. Skip hoisting for large mines gives lower costs of installation and operation, with greater reliability. Man-and-material hoists arranged to take care of every possible contingency against shut-down are advisable. Converting stations, is the logical method of supplying direct current to underground equipment.

ELECTRICALLY HEATED LEAD, SOLDER, AND BABBITT POTS

J. C. WOODSON[1]
Associate, A. I. E. E.

The uses of white metals of medium and low melting points are varied and many. Most of these go by the indefinite names of babbitts and solders though varying greatly in composition and correct operating temperatures. Most of these fall within the temperature range of 600 to 950 deg. fahr.

The ordinary method of melting and heating pots for these metals is by gas flames, the products of which pass directly into the work room. The regulation is poor and little attempt is made to control the pouring temperature. The electrical and automotive industries have made exhaustive studies along the lines of white metal bearing manufacture and these studies have invariably resulted in the conclusion that bearings must be poured at definite temperatures depending on the composition of the metal. This has led to the development and adoption of electrically heated, automatically controlled, melting pots for this work.

This type of pot has also been developed for higher temperatures for heat treating of steel and melting of aluminum and zinc, but those pots require special features to prevent rapid deterioration of the crucible.

It is pointed out that this branch of the electrical industry is comparatively young and undeveloped so that few standards have been adopted and the science of heat flow and heat measurements is likewise not as well developed as the other branches of the industry. Attention is called to the fact that most calculations and measurements are at present nothing more than approximations, resulting in a great deal of design being based upon results of tests and experiments, rather than theoretical considerations.

Certain types and sizes of pots now on the market are considered and analyzed. Several tables giving the salient facts concerning them are listed as well as characteristic curves and other data.

The general construction and design is gone into in detail and discussed. The importance of details and proper materials is pointed out.

For certain alloys the selection of the proper material for the vessel is the most important item of the whole

1. Simplex Wire & Cable Company, Boston, Mass.

**Presented at the Regional Meeting of Dist. No. 1, Swampscott, Mass., May 7-9, 1925.*

2. Allen & Garcia Co., Chicago.

†Presented at the Spring Convention of the A. I. E. E., held at St. Louis, Mo., April 13-17, 1925.

1. Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Presented at the Spring Convention of the A. I. E. E., St. Louis, Mo., April 13-17, 1925.

design as some alloys corrode the vessel very rapidly.

The theory of heat flow and heat loss is gone into and formulas given to calculate these quantities. Also, tables of constants are listed giving values to be used in these formulas.

The design and calculation of the resistor or heating elements is gone into fully as it is felt that most designs are not conservative enough; a curve of maximum wattages on the resistor is presented and recommended.

Performance curves are shown as well as numerous pictures of pots, installations, etc.

OPPORTUNITIES AND PROBLEMS IN THE ELECTRIC DISTRIBUTION SYSTEM*

D. K. BLAKE[1]
Associate, A. I. E. E.

An illustrative electric service system is analyzed to show the importance of the distribution system for the benefit of those not familiar with distribution problems. The diversity factor and load factor are employed to show their effect on investment and losses.

The important subject of a-c. secondary networks is discussed relative to switching, induction regulators and a-c. elevator equipments. The circumstances which make single pole switching preferable are outlined. A new, simple and effective connection of the control circuits of induction regulators to ensure stability in parallel operated circuits is described. The present status of a-c. elevator equipments is outlined with emphasis on the merits of Ward-Leonard control where high class service is required.

The new translator network is analyzed at length in order to show its performance and inherent difficulties. It gives a three-phase, four-wire, 115/230- volt system which in no way effects the consumers meters or utilization devices. The author's opinion is that it may be adopted on the grounds of company policy rather than on technical and engineering economic grounds.

Other distribution problems are briefly mentioned. Recent developments in carrier-current control for street lighting equipments are encouraging. Static condensers located at the load center of distribution circuits prove economical in some cases. Various automatic and remote control sectionalizing schemes are under consideration in order to restore service on feeders quickly.

IMPROVEMENT IN DISTRIBUTION METHODS*

S. B. HOOD[2]
Member, A. I. E. E.

The object of this paper is to point out how protective measures which have been applied to a low-voltage distribution network can be utilized to improve the operating characteristics of the entire distribution system, as well as materially lower its installation cost.

Many of the developments described in the paper are novel departures from more generally recognized practises. They have all, however, withstood the test of time and usage.

The common neutral system of distribution described has steadily increased in its application, since first developed by the author for use in Toronto, Canada, about 16 years ago. It is at present the standard system with a number of large utilities with an aggregate capacity of some 300,000 kw. The particular system described is that of the Northern States Power Company in the Minneapolis territory, representing about 60,000 kw., or about one-half the total output of this widespread organization.

The heavy duty a-c. underground network and the remote-control multiple street lighting systems described, are both later developments that are more or less interrelated with this common neutral development.

1. Central Station Engineering Department, General Electric Company, Schenectady, New York.

2. Of the Northern States Power Company, Minneapolis, Minn.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-19, 1925.

HYDROELECTRIC DEVELOPMENT OF THE SAGUENAY RIVER AT ISLE MALIGNE

W. S. LEE[1]
Fellow, A. I. E. E.

The largest single installation in water-power development ever undertaken is at Isle Maligne on the Saguenay River, Province of Quebec, Canada, where a total power-house installation of 540,000 h. p. is being made, of which 360,000 h. p. is completely, and 180,000 h. p. partially installed.

The building of the Isle Maligne Station in a remote section with extreme difficulties due to weather and floods, called for very careful planning and coordination of the various parts of the work. The steps in the construction of this plant are shown perhaps at rather extreme length, but this is done largely to bring out the value and importance of designing with the idea of cooperating and coordinating with the contractor or the construction forces. The design and layout of the construction plant were given as much attention on this work as the design of the powerhouse. The writer maintains and endeavors to impress upon designing and construction engineers of any large project, this very important cooperative feature. Had this not been done at the Isle Maligne Station, the great amount of work could never have been executed in the same length of time.

1. Southern Power Co., Charlotte, N. C.

Presented at the Annual Convention of the A. I. E. E., Saratoga Springs, June 22-26, 1925.

TRANSMISSION LINE DESIGN—II

The Line of Maximum Economy

F. K. KIRSTEN[1] and E. A. LOEW[1]
Member, A. I. E. E. Member, A. I. E. E.

A rational method is developed for the complete design of a transmission line. The most economical conductor diameter together with the most economical transmission line voltage are found from Kelvin's Law applied so as to include all cost factors which vary with the conductor area. Rational formulas are developed for finding conductor spacings for both single circuit and double circuit towers. A method is developed for finding the most economical tower heights and spacings. The influence of this method of design upon the line constants is pointed out. A worked out problem is presented to illustrate the use of the method proposed, and vector diagrams are included, showing the complete line performance at both the generator and receiver ends of the line.

This paper is divided into three sections as follows:

Section A: Kelvin's Law applied to the complete design of transmission lines. The line of maximum economy.

Section B: The influence of the principle of maximum economy, as applied to transmission line design, upon the electrical performance. Line constants and vector diagrams.

Section C: Solution of typical problem illustrating the use of the principles developed in Sections A and B.

1. Both of the University of Washington, Seattle, Wash. See also Univ. of Washington Engineering Experiment Station Bulletin No. 32, Transmission Line Design, Part II, by F. K. Kirsten and E. A. Loew.

Presented at the Pacific Coast Convention of the A. I. E. E., Seattle, Wash., Sept. 15-17, 1925.

SELF-INDUCTANCE AN AMBIGUOUS TERM

BY CARL HERING

Electrical nomenclature is no doubt more precise and better defined than that in all allied branches of science, but the term self-inductance is a marked exception; it is, in fact, a jumble of a number of different things. Originally it seemed to be applied chiefly to a sort of impedance to the starting of a current, like inertia in starting a body to move. Then it was interpreted as a function of the energy stored by overcoming this impedance, like the $m\,v^2/2$ energy of a moving body; then as a function of the number of flux lines in which this energy was stored. But physically it is a purely geometric quantity and is said to be a mere length, hence it should be entirely independent of any electrical or magnetic quantities, yet notwithstanding this it is generally defined purely electrically, as the flux per ampere.

Assume a single-turn, circular circuit. When a current is started and allowed to reach its final steady value, the following are involved: (1) the current in each part may be said to induce a *direct* e. m. f. in its corresponding part of the return circuit (as for instance in the extreme case of a so-called non-inductive circuit); this aids and does not impede the starting of a current, hence is *opposite* to the impedance usually implied; this does not seem to involve a storage of any energy, although some flux was involved; some energy has however, been transferred from one part to the other by flux. But it may be claimed by some that this induction on itself is not a self-inductance.

(2) The current in every filamentary conductor induces a *counter* e. m. f. in every other one, or in every neighboring conductor if there are a number of turns; this impedes the starting of the current just as inertia impedes an increase of velocity in mechanics; overcoming this kind of an impedance stores energy in both the electrical and the mechanical cases; the product of the momentary current and the momentary counter e. m. f. would give the energy stored at that moment, but only if they are in phase, which is being assumed, but perhaps without sufficient proof. Both (1) and (2) are true cases of induction of an e. m. f. by a cutting or linking of flux lines; but a variable part of these lines (the internal ones) cut or link only a fractional part of the conductor hence have a lesser inducing effect than the others, and as they also have a lesser m. m. f. they are claimed to represent less energy per line.

(3) This transient e. m. f. causes a temporary unequal distribution of the current in the cross section of the wire, hence resistance enters, as it does in the skin effect.

(4) Starting a current is like starting a body into motion, energy is required to do it and this energy is thereby stored like that in a spinning top, and it resides in the flux in the electrical case; hence self-inductance in this sense involves a true storage of flux energy besides a true induction of an e. m. f. Yet it is easily shown that the induced e. m. f. is entirely independent of the energy residing in the flux which is cut or linked; the e. m. f. might be large and the flux energy small, or vice versa. Yet both are being calculated independently from the same self-inductance.

(5) In the calculation of this flux energy, it seems now that in some cases the energies of components were added to that of their resultant, thereby giving too large a result.

(6) Self-inductance being a purely geometric quantity, should be independent of such factors as the frequency, phase difference, skin effect, etc., but as usually interpreted it is not.

(7) A feature which is confusing (though explainable) is that the flux and stored flux energy of a coil of a given size and shape are said to be dependent only on the m. m. f. in ampere-turns (for unity permeability) and not at all on the number of turns, yet the self-inductance from which this same stored energy is calculated, varies very greatly with the number of turns, as their square.

(8) When iron is present everything is changed. All these various and different factors, elements or features and perhaps more, have been jumbled together in this one quantity termed self-inductance, which physics tells us is nothing more or less than a mere length. It seems now that fundamentally the true meaning of this length is merely that it is the length of the path of the current, or the length of the pile of its disks of flux (the centerline length). If so, its other meanings should be more carefully differentiated from this and from each other. A revision is needed. We should start with better fundamentals. In the opinion of the writer the calculated energy attributed to flux has sometimes been greater than it should be, due to adding things which had already been added.

ILLUMINATION ITEMS

By the Lighting and Illumination Committee

BRIGHTER SCREENS FROM PORTABLE PROJECTORS

Several major improvements have recently been made in lamps for portable motion picture projectors. One of the most popular forms of projector is the suitcase type. A 400-watt, T-20 bulb lamps was the standard for this service. A greater wattage and higher screen illumination were often desired but the limited space available for the lamp made these impossible of realization until recently.

Progress in design has now made possible a 500-watt lamp in a bulb of the same overall dimension. The result is greater than the increased wattage alone would indicate, for the lamps can now be made so uniform that the long demanded fifty-hour life supplants the old one-hundred-hour rating. The combined result is an increase of a full third in screen illumination. The new lamps are applicable to the projectors already in service; with some regulating the resistance must be changed.

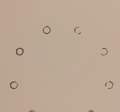


Fig. 1

Fig. 2

It has been possible to apply the shorter-life design to the other tubular bulb, projector lamps for portable equipments and the screen illumination has been increased from eight to ten per cent without change in wattage. The demand for this shorter-life lamp is readily apparent from the fact that the cost of lamps is only from one to two per cent of the cost of showing pictures and this is entirely outweighed by the brighter screen.

A new method of disposing the filament of the 1000-watt, 110-volt lamp for semi-portable equipments has effected an increase of fifteen to twenty per cent in screen brightness, varying with the projection lens employed. A cross-section of the old or barrel form is shown in Fig. 1. The new form is a section of a cylinder as indicated in Fig. 2. This form of light source permits light from all of the coils to reach the condensing lens, as is not the case when the barrel form is used.

The life of the round-bulb, concentrated-filament lamps, designed for spotlight service, has been increased from 100-to-200-hours rated average. The conditions of the service for which these lamps are designed are such that the lamp is burned for several hours at a time and the necessary illumination can be obtained by the use of several spotlights rather than operating the lamps at extreme efficiencies as is necessary for lamps used for the projection of transparencies. These changes make it necessary to distinguish carefully between the service for which the two types of lamps are to be used. The tubular-bulb lamps are intended for motion picture and lantern slide projection and the round or spherical bulb lamps should be used in spotlights. The round-bulb lamps designed for spotlight service should not be confused with the lamps of similar rating intended for floodlighting service which have a life of 800 hours. The larger source and lower efficiency of this latter type render it unsatisfactory for spotlight purposes.—*Light,* November, 1925.

CHROMIUM-COATED AUTO LIGHT RESISTS WEAR AND TARNISH

Auto headlamps and outdoor, floodlight reflectors that are said to be as efficient as freshly silvered glass mirrors have been developed by using a coating of polished chromium. This metal, unlike aluminum, silver or nickel, will not tarnish or corrode although subjected to constant exposure, and is so hard that gritty waste may be used in cleaning it without danger of scratching. It need not be coated with lacquer to protect it from the atmosphere; hence the full benefit of its brightness is obtained.

UNIQUE FOUNTAIN KEEPS TIME TO MUSIC

Two illuminating fountains which automatically synchronize their light and the movements of their waters with radio music have been installed in the San Francisco civic center. By means of a special attachment, the tempo and the loudness of the tones modify or increase the force of the jets and change the lights, which are of four different colors. As the volume of the radio signals varies, the jets rise or fall and the lights shine through the spray so that the music selection is "reproduced" in color and motion.

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The Institute is not responsible for the statements and opinions given in the papers and discussions published herein. These are the views of individuals to whom they are credited and are not binding on the membership as a whole.

Timely Subjects on Program of Midwinter Convention

A number of very timely topics will be covered by the program about completed for the Midwinter Convention of the A. I. E. E., to be held in New York, February 8-11, 1926. Among the subjects discussed will be transmission, protective systems and distribution, electrical machinery, communication, insulation and dielectrics, electromagnetism and measurements.

The local convention committee, which has charge of entertainment, etc., will arrange some very delightful features including a dinner-dance, smoker, inspection trips, etc. The general committee appointed by the President consists of H. A. Kidder, Chairman, H. H. Barnes, Jr., G. L. Knight, E. B. Meyer and L. F. Morehouse.

National Nominating Committee

The National Nominating Committee of the Institute will meet at Institute headquarters, New York, early in December, to nominate candidates to be voted upon at the Institute election next spring, in accordance with the provisions of the constitution and by-laws as published in the October JOURNAL.

The personnel of this committee, as selected by the executive committees of the various Geographical Districts and by the Board of Directors, is as follows: District No. 1, G. Faccioli, Pittsfield, Mass.; District No. 2, N. W. Storer, Pittsburgh, Pa.; District No. 3, Gano Dunn, New York City; District No. 4, A. M. Schoen, Atlanta, Ga.; District No. 5, J. E. Kearns, Chicago, Ill.; District No. 6, W. H. Edmunds, Denver, Colo.; District No. 7, T. C. Ruhling, Kansas City, Mo.; District No. 8, W. G. Vincent, Jr., San Francisco, Calif.; District No. 9, H. P. Cramer, Portland, Ore.; District No. 10, W. P. Dobson, Toronto, Ont.; Directors, M. M. Fowler, Chicago, Ill., E. B. Merriam, Schenectady, N. Y., L. F. Morehouse, New York City, A. G. Pierce, Cleveland, Ohio, Harold B. Smith, Worcester, Mass.

FUTURE SECTION MEETINGS

Boston

Address Broadcast Via Radio from Station WBZ. December 9.

Latest Design and Practise in Power Plants, by Vern E. Alden. Joint with A. S. M. E. Lorimer Hall, Tremont Temple. January 14.

Connecticut

Distribution Problems, by J. E. King. Waterbury. December 9.

Maintenance of Industrial Equipment. Hartford. January 19.

New York

A meeting of the New York Section of the Institute will be held at 8 P. M. on the evening of Friday, December 18, 1925 in the Auditorium, Engineering Societies Building, 33 West 39th St., New York, N. Y. The paper to be discussed will deal with new and interesting developments in telephone cable lines and will be entitled *Long Distance Underground Telephone Cable Communication*," by J. J. Pilliod, Engineer, Long Line Dept., American Tel. & Tel. Co., New York, N. Y.

St. Louis

Engineering Research, by H. H. Dewey, General Electric Co., December 16.

Long-Distance Cable Communication for St. Louis, by H. H. Nance, American Tel. & Tel. Co. January 20.

New York Electrical Society Meeting

A meeting of the New York Electrical Society will be held in the auditorium, Engineering Societies Building, 29 West 39th Street, New York, N. Y. at 8 p. m. on the evening of Wednesday, December 9, 1925. The meeting will be of a rather novel nature as it will be devoted to an "Evening with the Movies," being an exposition of the latest developments in engineering and science. The picture will be accompanied by music furnished by an excellent orchestra. The Society extends a cordial invitation to attend to all interested engineers and their friends.

Meeting of American Institute of Chemical Engineers

The eighteenth annual meeting of the American Institute of Chemical Engineers will be held at the Hotel Sinton, Cincinnati, Ohio, December 2-5. An enjoyable and instructive program has been arranged and transportation for members will be cared for by a special schedule on the new Baltimore and Ohio train, the National Limited, through J. C. Olsen, Secretary.

Meeting on Industrial Cooperation With War Department

Industrial preparedness as insurance against war will be the topic of a meeting to be held in the auditorium of the Engineering Societies Building, 33 West 39th Street, New York, at 8:30 P. M., Friday, December 4, 1925. The speakers will be Dwight F. Davis, Secretary of War; Hanford MacNider, Assistant Secretary of War, and General James G. Harbord, President of the Radio Corporation of America. The Honorable Elbert H. Gary, Chairman, Advisory Board, New York Ordnance District, will preside. Engineers, chemists and manufacturers, particularly, will be interested in the meeting and they are invited to be present as an indication of their support of the War Department

in its program on this subject. Ladies will be cordially welcomed. The committee on arrangements consists of representatives of the Army Ordnance Association and six engineering societies including the American Institute of Electrical Engineers.

The Midwest Power Conference

Plans are being perfected for a Power Conference to be held in Chicago, January 26-29, the committee in charge consisting of Arthur L. Rice, chairman, G. E. Pfisterer, secretary, with two committee members each from the American Institute of Mining Engineers, The American Society of Mechanical Engineers, the National Safety Council, the National Electric Light Association, the Western Society of Engineers and the American Institute of Electrical Engineers. It is proposed that, at the first meeting, the conference will take up the subject of the power resources of the country; this will be followed by a second meeting for the consideration of the best ways and means to utilize these resources. Thursday afternoon will be left open for inspection trips to the various power stations and developments in and about Chicago, by way of gaining further information helpful to the cause.

American Association for the Advancement Of Science

The meeting of Section M (Engineering) of the American Association for the Advancement of Science will be held in Kansas City, Wednesday, December 30, 1925, in connection with the annual convention of the Association. All interested are welcome to attend. The opening address will be by Dr. A. E. Kennelly, Professor of Electrical Engineering, Harvard University and retiring chairman of Section M. This will be followed by the further addresses; The Relation of Map Making to the Progress of Civilization, by Col. E. Lester Jones, Director of the U. S. Coast Geodetic Survey; Contributions of Seismology to Engineering Design, by Dr. James B. MacElwane, St. Louis University; Human Engineering, by Dean Hugh Miller, George Washington University, and a round table discussion on "The Relation of the Professional Engineering Societies to the American Association for the Advancement of Science." President M. I. Pupin will preside at the evening session and will offer an address on "The Relation between Pure and Applied Science." This talk, with possibly two additional speakers of national prominence as engineers and scientists, will close the meeting.

Fourth American Radio Conference

The Fourth Radio Conference was held in Washington, D. C., during the week of November 9, under the direction of Herbert Hoover, Secretary of Commerce, who acted as chairman.

About four hundred, delegates, representing the Broadcast stations, manufacturers, commercial radio telegraph companies, the listening public, radio telegraph amateurs, Government departments, radio engineers Institute and other interests concerned in the subject, attended the Conference.

The Conference endorsed the proposal that the broadcast band, ranging from 202 to 545 meters, as at present, be allowed to remain intact and without extensions on either side of the scale.

Five years was proposed as the duration of broadcast station licenses, with fees ranging from $25.00 to $2000.00 per station, and although there was much opposition to any form of governmental control of the art, it is understood that the recommendations of the Conference are to form the basis of a bill to be sponsored by Chairman White of the House Radio Subcommittee.

In dealing with the problem of advertising by radio, the Conference expressed itself as opposed to direct methods of advertising and called upon the members, themselves. to keep radio as free from this practise in the future as it had in the past. It was decided that the burden of keeping the air free of direct advertising should fall upon the broadcasters rather than upon the Government and that no legislation was necessary at this time.

It was recommended that, inasmuch as the distinction between Class A and B stations is purely artificial, this terminology should be discontinued. The licensing and classification committee also suggested that a permit for the construction of a station should be necessary before the building operation was commenced, in order that the owner might be assured of a wave length when the station was complete.

The Department of Commerce was urged to decrease the number of stations by refusing to grant any more wave lengths, and likewise refusing any more operating permits, until such time as the mortality of stations had created a demand. This resolution was passed in different forms by several of the committees and accepted unanimously by the convention.

Re-broadcasting will not be permitted without the specific consent of the station providing the program.

It was felt that the matter of interference from radiating receiving sets should take the form of persuasion rather than coercion and that such interference could better be eliminated by giving publicity to methods of operating these receivers in such a manner that they would not radiate.

Dr. A. E. Kennelly represented the A. I. E. E. at this conference.

Corrections in Standards Pamphlets

Section 10—Standards for Direct and Alternating Current Fractional Horsepower Motors.

In the final printing of Section 10, a part of paragraph 10-450 and all of paragraph 10-500 dropped out by the failure to print page 11. Those having copies with page 11 blank can obtain perfect copies by returning the incomplete pamphlet to headquarters. Address H. E. Farrer, Secretary, Standards Committee, A. I. E. E., 33 West 39th St., New York.

Section 30—Standards for Wires and Cables

In the footnote 30-101, page 7, the denominator of the formula for k should be written with a plus (+) sign immediately following the expression $\frac{W\ R}{l^2}$, and not a division sign as printed at present.

Accident Prevention Conference

In the campaign to reduce the loss of life due to preventable accidents—a figure said to reach 83,000 annually—the National Safety Council, in cooperation with the New York Sections of the national societies of Civil, Mechanical, Mining and Electrical Engineers, held a meeting at the Engineering Societies Building, 33 West 39th St., New York, on Wednesday, November 18, 1925.

At the morning session, two addresses were presented. In the opening talk, C. B. Auel, Past President, National Safety Council, characterized accident prevention as "the greatest economic problem that ever confronted our country." He was followed by W. C. Dickerman, Vice President, American Car & Foundry Co. in "Economic Aspects of Safety." Discussion by Prof. W. Rantenstrauch, Columbia and L. P. Alford, Editor, Management and Administration. Other speakers at this session were H. W. Forster, Independence Bureau, Philadelphia; Harry Schultz, United States Steel Corp., and W. E. McGavick, President Yellow Cab Co. The presiding officer at this session was Kingsley Martin, Chairman, Metropolitan Sections A. S. M. E.

The afternoon session had as its presiding officer, Robert Ridgeway, President A. S. C. E. The speakers were C. E. Skinner, Westinghouse Elec. & Mfg. Co., and Dean E. A. Holbrook, School of Mines, University of Pennsylvania, with discussion by C. P. Tolman, Consulting Engr., L. A. DeBlois, E. I. du Pont de Nemours & Co., Prof. J. D. Keller, Penn State College, and A. W. Whitney, National Bureau of Casualty and

Society Underwriters. Particular attention was called to the necessity of teaching the principles of safety to school children of whom 20,000 are killed annually by accidents. In the three cities of Detroit, St. Louis and Rochester where courses of instruction in accident prevention have been carried out the fatalities have been reduced 50 per cent. A demonstration of the Prone Pressure Method of Resuscitation was given by S. W. Ashe of the G. E. Co.

At the evening session Doctor M. I. Pupin, President of the A. I. E. E., presided. The other speakers were, J. V. Reynders, President A. I. M. E.; B. F. Tillson, New Jersey Zinc Co., and John W. Lieb, New York Edison Co. Mr. Reynders pointed out that there were eight times as many people killed yearly by motor vehicles as there are in mines.

The total attendance at the three sessions was in the neighborhood of 1000. Those interested in obtaining copies of the addresses should apply to W. D. Keefer, 168 N. Michigan Ave., Chicago, Ill.

American Society of Agricultural Engineers

The Fall Meeting of the North Atlantic Section of the American Society of Agricultural Engineers will be held December 10-12 inclusive at Schenectady, New York with headquarters at the Hotel Van Curler. Problems under discussion will be those relating to Federal Funds for agricultural education, its organization under various States and Federal agencies, rural electrification, farm power machinery and farm building with reference to remodeling sanitation and upkeep. The address of welcome will be delivered by F. A. Wirt.

West Point Military Academy Admitted to American Universities Association

At the recent annual meeting of the Association of American Universities, in New Haven, the admission of United States Military Academy at West Point to membership under the class of Technological Institutions was formally approved. This approval was voted after a careful investigation of the curriculum and collegiate standards maintained in the educational training of West Point had been satisfactorily and duly accomplished. The immediate effect of the military academy's membership in the Association will be to give to any of its graduates selected as Rhodes scholars, a regular senior standing at Oxford, as the Association of American Universities is recognized by the English universities and graduates of universities, colleges and technical schools upon the Association's accredited list are given senior rating without question.

A-C. or D-C. Low-Tension Distribution for Manhattan?

At the forty-first annual meeting of the Association of Edison Illuminating Companies, held during the week of October 19th, at the Arlington Hotel, Hot Springs, Ark., Mr. Dugald C. Jackson, of the Massachusetts Institute of Technology and past-President of the Institute, presented a valuable paper on the subject of "Electrical Distribution in Very Congested Territory." Mr. Jackson stated that "the results of comparative analysis of d-c. and a-c., low-tension distribution for Manhattan are notably in favor of the d-c., fortified by storage batteries from a physical standpoint." He stated that the d-c. distribution system with associated storage batteries has produced a result which is of outstanding service; namely, providing continuous, well-regulated and uninterrupted supply of electric power to the distribution mains through all the vicissitudes of electrical plant operation.

National Research Council

INTERNATIONAL CRITICAL TABLES NOW IN PUBLISHED FORM

The National Research Council has contracted for the publication of the International Critical Tables of Numerical Data of Physics, Chemistry and Technology. These will be issued in five volumes, with reserved rights to all individual members of scientific and engineering societies to purchase them at the cost of $35.00, providing applications are received by the Engineering Research Council, B and Twenty-First Streets, Washington, D. C., prior to the publication of the first volume, which is scheduled for early in the year 1926. The price after publication of the first volume will be $60.00 for the complete set.

The scope of the material collected covers all available information of value concerning the physical properties and numerical characteristics of (a) pure substances, (b) mixtures of definite composition, (c) the important classes of industrial materials, (d) many natural materials and products, and (e) selected data for selected bodies or systems, such as the earth and its main physical subdivisions and the solar and stellar systems. Publications of the world in all languages have been combed for data and much unpublished information has also been collected.

In addition to their wide scope, the Tables will contain many novel features of arrangement. Thus, for example, not only will it be possible to find readily all of the properties of a given substance or material, but it will also be possible in many cases to ascertain readily what substance or material of a given kind has a maximum, a minimum, or a given value for any given property. This feature will be of great assistance in identifying a substance by means of its properties or in selecting a substance or material on the basis of a given property or combination of properties.

The principal language employed will be English; but much of the explanatory text, the tables of contents, and the very complete index, will be given also in French, German, and Italian.

Saskatchewan Section Holds First Meeting

The most recently organized Section of the Institute, the Saskatchewan Section, held its first meeting in Regina on October 23. Officers were elected and an interesting paper, *Power Supply for Cities of Saskatchewan* was read by E. W. Bull, Superintendent of Light and Power, City of Regina.

Officers were elected as follows: Chairman, E. W. Bull; Secretary-Treasurer, W. O. Brattle; Executive Committee members, S. R. Parker, J. D. Peters, W. T. Hunt, A. Townsend and A. W. Hooper.

Steps Recommended to Promote Civil Aviation in United States

Recommendations for the measures necessary to encourage the civil use of aircraft in the United States and a complete survey of the present legal, governmental, commercial and public relations of civil aviation are included in a report which has been prepared by a joint committee of the Department of Commerce and the American Engineering Council.

Realizing that, in spite of many naturally favorable conditions, air transportation in this country has not achieved a development commensurate with the great opportunities at hand, these bodies appointed the committee to make a comprehensive survey of the commercial and economic aspects of aviation throughout the world. The committee found that certain fundamental difficulties are retarding the development in this country and it drew up recommendations for removing these handicaps. These

recommendations, under four general headings are, as shown in the following paragraphs:

RECOMMENDATIONS FOR PROMOTION OF CIVIL AVIATION IN THE UNITED STATES

I. Legal Status and Control

1. That Congress enact a civil aeronautics law providing for
   a. Establishment of a bureau of civil aeronautics in the Department of Commerce with power:
      1. To regulate civil air navigation in the United States.
      2. To license pilots and inspect and register aircrafts.
      3. To develop, establish or take over and maintain air routes and air-navigation facilities.
      4. To administer international air-navigation regulations as they affect the United States.
      5. To encourage and promote civil air transport and the aircraft industry and trade.
      6. To determine and impose civil penalties for violations of regulations.
   b. Recognition of the public right of free air navigation.
   c. Defining the liability of common carriers engaged in air transportation in interstate and foreign commerce.
   d. Reconciliation of the rules of water navigation with air navigation.
   e. Correlation of the laws relating to customs, public health; imports and exports, and other laws of general scope with the civil aeronautics law to recognize carriage of goods and passengers by air.

2. That the several states enact statutes authorizing the municipalities to acquire and maintain with public funds and to lease landing fields, and that for the present the other phases of state jurisdiction relative to aeronautics be permitted to develop under the common law.

3. That the President submit to the Senate and that the Senate ratify with suitable reservations the International Air Navigation Convention, which has been signed by representatives of the United States and has been ratified by most of the important countries except the United States.

II. Government Program Regarding Civil and Industrial Uses of Aircraft

1. That the Government do not engage in non-military flying activities which can be properly performed by private operation.

2. That the Government extend the use of aircraft in non-military government activities where aircraft may be usefully employed, such as air mail, forest patrol, agricultural, entomological and Coast Guard services, aerial photography, map making, etc., the operations to be conducted by private agencies under contract wherever possible.

3. That, under the legislation recommended, the Federal Government without delay provide air transportation with essential facilities such as lighted airways, emergency fields, maps, radio and an adequate weather service.

4. That Congress authorize the War and Navy, and other Departments, to permit a reasonable use of Government landing fields and ground facilities for commercial aircraft operations.

5. That the Post Office Department actively encourage the establishment and extension of air mail services and that as rapidly as it is possible to contract with responsible private operators, the Post Office Department retire from the ownership and operation of such air mail routes, and that it turn over to the Bureau of Civil Aeronautics its airway equipment.

6. That, under the direction of the President, the executive heads of the Departments concerned shall provide for the inter-departmental coordination of all non-military Government air activities in order best to promote civil aviation.

III. Commercial Aircraft and Equipment

1. That Congress appropriate for, and authorize the proper non-military agencies of the Government to purchase special types of civil aircraft and equipment, designed and constructed by private industry under the joint direction of the executive heads of all the departments concerned.

2. That present restrictions affecting purchases by governmental agencies be modified to permit the executive heads of the Department concerned to purchase aircraft, aircraft engines, accessories and parts in such a way as best to promote the government's interest and to give equitable compensation to the manufacturer for the design development pertaining to the materials so purchased.

3. That Government purchases of aircraft be arranged to conform to a definite and continuous program, which will give the greatest aid to the aircraft industry.

4. That the Government carry on fundamental aeronautical research in the interest of civil aviation.

5. That the Government do not compete in the design, construction and major repair of civil aircraft, nor handicap civil aviation by indiscriminate dumping of aeronautical material.

6. That the Government adopt a policy of facilitating the exportation of commercial aircraft, which thereby extends to the manufacturers a benefit which of necessity will result advantageously to the Government as the principal customer of the aircraft industry.

IV. Public and Business Support

1. That aircraft underwriters base insurance rates to responsible aircraft operators on their record of performance, rather than upon average figures which include military hazards and the performance of irresponsible itinerant flyers.

2. That life and accident insurance companies reconsider the risks incident to specific types of flying, and modify accordingly their restrictions on aeronautical activities of policy holders.

3. That financial agencies and others should invest in civil aviation enterprises only with full knowledge of the integrity and competence of all involved and careful scrutiny of the proposed financing, routes, equipment, depreciation rates, operating personnel, and probable character, sources and volume of traffic.

A summary of the findings and recommendations has been issued and the complete report will be published in the near future.

ENGINEERING FOUNDATION

AIRCRAFT PROTECTIVE MEASURES

"To lessen the danger of disasters to aircraft and other structures, The Engineering Foundation," says Mr. Alfred D. Flinn, Director, "is endeavoring to incite an exhaustive study of the fatigue of metals." This is pursuant to a declaration by the official journal of the American Chemical Society that further knowledge of the fatigue of metals is essential to guard against repetition of mishap to aircraft, such as the tragic fate of the Shenandoah.

AMERICAN ENGINEERING COUNCIL

COMMITTEE TO REVIEW GIANT POWER REPORT

The Administrative Board of the American Engineering Council, meeting the latter part of October at Columbus, Ohio, authorized the appointment of a committee to review and analyze the Giant Power Report issued by Governor Pinchot of Pennsylvania. The reviewing committee will be chosen by the Executive Committee of the Council, to which it will return a report at the earliest possible moment.

Joint Research Committee on Effect of Temperature on Metal

A meeting of the joint research committee on the Effect of Temperature on the Properties of Metals, sponsored by the American Society of Mechanical Engineers and the American Society for Testing Materials was held at the Cleveland Hotel, Cleveland, Ohio, October 25th. The Subcommittee on Cooperative Laboratories, through its head, C. T. Malcolm, reported that practically all laboratories addressed had expressed willingness to cooperate in these investigations to the limit of their facilities.

The American Physical Society to Hold 27th Annual Meeting in Kansas City

The 27th annual meeting of the American Physical Society will be held in Kansas City, December 28-30, 1925, in conjunction with Section B—Physics—of the American Association for the Advancement of Science. Professor K. T. Compton will give the annual address, on "Dielectric Constants and Molecular Structure" and this will be followed by a symposium on relativity, which will include papers by Prof. H. G. Gale of the University of Chicago, Prof. A. C. Lunn, also of the University of Chicago, and Dr. Charles E. St. John, of the Mt. Wilson Observatory.

Further Montefiore Medal Awards

There appeared in the November issue of the Institute's JOURNAL, notice of the award of the Montefiore Medal to Doctor J. B. Whitehead. Since this publication, we have been informed

of further awards as follows: First award to Frederick Creedy, London, England, for "Some Developments in Multispeed Cascade Induction Motors" and "Variable Speed Alternating Current Motors without Commutators," with an award of 6000 francs; and Second awards to Dr. Whitehead and to Mr. Chechelowsky, engineer and electrician of the Anvers Institute, for "Study on Operating and Releasing Times of Telephone Relays," each receiving an award of 4000 francs.

Industrial and Scientific Museums Discussed by Dr. von Miller

Plans for industrial and scientific museums and particularly a Museum of the Peaceful Arts, proposed for the City of New York were given impetus by Dr. Oscar von Miller, founder and Director of the Deutsches Museum of Munich, through an address which he gave on November 23 in the Engineering Societies Building, New York.

Dr. von Miller has come to this country to advise in formulating plans for industrial and scientific museums following the ideas of the great Munich Museum. He described and showed by lantern slides, features of that Museum and told of the principles of its establishment.

The address was made at a meeting held under the auspices of the Association for the Establishment and Maintenance for the People in the City of New York of Museums of the Peaceful Arts. Other organizations cooperated, including the American Institute of Electrical Engineers. Dr. G. F. Kunz, president of the Museum of Peaceful Arts, presided. Other addresses were made by Dr. J. V. W. Reynders, president of the American Institute of Mining and Metallurgical Engineers, John W. Lieb, past-president, American Institute of Electrical Engineers, and Dr. Charles Reese, of the Du Pont Company.

The Chandler Memorial

Elihu Root, addressing a Chandler memorial meeting of the American Chemical Society, Havemeyer Hall, Columbia College, Monday evening, November 16th, characterized the late Charles F. Chandler as an "outstanding American who had the genius of public service." Extolling Professor Chandler as the founder of the Columbia School of Mines and the American Chemical Society, Mr. Root continued describing him as "possessed of a quality of clear and unhesitating courage, forgetful of self and ambitious for concentrated effort of accomplishment." President Butler's tribute to Professor Chandler was an exhortation "not to express sorrow in the heart at his loss but rather to sound the note of triumph for his enduring leadership." Doctor M. I. Pupin, whose address on "Chandler, the Teacher and Chemist" is published elsewhere in this issue of the Journal, also added affectionate acclaim of Professor Chandler's undying worth to humanity in general, as well as to the science.

Norcross Memorial Unveiled

A tablet to the memory of the late Paul Howes Norcross, member of the American Society of Civil Engineers and American Institute of Consulting Engineers, who was lost in the Norman boat disaster on the Mississippi River, May 1925, was erected on the grounds of Georgia School of Technology, his Alma Mater, by his fellow engineers and unveiled October 30th with appropriate ceremonies witnessed by a representative group of students, friends and engineers from distant points. The principal address, "The Contributions of Paul Norcross to the Engineering Profession" was made by Robert Ridgway, president of the American Society of Civil Engineers, who paid high tribute to Mr. Norcross for his public spirit and engineering ability.

Chemical Bibliographies

A Bibliography of Bibliographies on Chemistry and Chemical Technology, 1900-1924, by Clarence J. West and D. D. Berolzeimer, is announced by the National Research Council, Washington, D. C., as their Bulletin No. 50 (308 p., $2.50). This work is composed of the following sections: General Bibliographies, Abstract Journals and Year-Books, General Indexes of Serials, Bibliographies of Special Subjects and Personal Bibliographies. As the title indicates, the work is a compilation of bibliographies published as separates, or at the end of books or magazine articles, or as footnotes to the same, on the numerous aspects of pure and applied chemistry. Each entry gives name of author or compiler, title, and place of publication. The majority of the entries state the number of references, thus giving an indication of the completeness of the particular bibliography. The entries are classified under the proper subject-headings, alphabetically arranged. The duplication of individual entries has been largely avoided by the liberal use of cross-references. An approximate analysis shows that there are about 2400 subject headings, 7500 author entries and a total of 10,000 individual bibliographies. Although no claim is made for the completeness of the compilation, it is believed that the work will furnish a convenient starting point for any bibliographic search.

Appointment of Executive Committee of Highway Research Board

The following officers and members have received appointment as an executive committee for the Highway Research Board: Chairman, A. N. Johnson, Dean, College of Engineering, University of Maryland; vice-chairman, W. H. Connell, Engineering Executive, Pennsylvania State Highway Department; director, Charles M. Upham, State Highway Engineer, North Carolina; T. R. Agg, Iowa State College; A. J. Brosseau, President of the Mack Truck, Inc.; H. C. Dickinson, Chief, Bureau of Public Roads, U. S. Dept. of Agriculture and Wm. Spraragen, Secretary Engineering and Industrial Research, National Research Council.

PERSONAL MENTION

Theodore Schou, chief engineer of The Ideal Electric & Manufacturing Co., Mansfield, Ohio, has just returned from a four months' sojourn in Europe.

Manfred K. Toeppen has resigned from the position of chief engineer of the Michigan Public Utilities Commission, and has opened consulting offices of his own in Detroit.

Mortimer Silverman has left the service of the Commonwealth of Massachusetts, with whom he has been for some time as engineer for the Commission on Administration and Finance, and has entered the employ of the Boston & Maine Railroad as assistant to the chairman of the executive committee.

Thomas F. Flynn, formerly with the engineering department of the New York State Public Service Commission, has recently established his own office in Albany, specializing on inventories and appraisals, classified accounting and property reports for public utilities and mining and industrial plants.

W. H. Patterson, formerly vice-president of the Kaestner & Hecht Elevator Company of Chicago and later vice-president of the John H. Dunham Advertising Agency of that city, has joined the Industrial Sales Department of the Westinghouse Electric & Manufacturing Company at East Pittsburgh. Mr. Patterson will be in charge of the building industries division of the department.

Obituary

George Young Allen, Associate of the Institute, was killed November 12th, when a Pennsylvania train telescoped the rear end of the express train on which Mr. Allen was returning from the Fourth National Radio Conference held at Washington, D. C. Though only thirty-two, Mr. Allen was already a conspicuous figure in radio activities, at the time of his death being technical assistant to the manager of the Radio Department of the Westinghouse Electric & Manufacturing Company. Born at Bernardsville, New Jersey, 1893, his general education was through the local grammar and High School. Immediately thereafter he entered Stevens Institute of Technology and graduated with an M. E. degree in 1915. This was followed by a post graduate course in alternating current at the Massachusetts Institute of Technology, completed in 1917. From 1915 to 1916 he was employed in the Physical Laboratory of the Western Electric Company and from 1916 to 1917, in the Research Laboratory of the Massachusetts Institute of Technology, having been transferred by the Western Electric Company to the American Telephone and Telegraph Company and assigned to this work by them. In August 1917, he entered the Radio Division of the Bureau of Steam Engineering, Navy Department, where he remained until his connection with the Westinghouse Company in 1919. Beside being an Associate of the Institute, Mr. Allen was also a member of the Institute of Radio Engineers, the National Electric Light Association and the Associated Manufacturers of Electrical Supplies. Mr. Mallory, Manager of the Radio Department of the Westinghouse Company pays him the following tribute: "Brilliant as an engineer; indefatigable as a worker; charming of personality—it will be impossible to replace him."

Harold W. Nichols, a radio research engineer of Bell Telephone Laboratories, died on November 14th at his home in Maplewood, New Jersey. Dr. Nichols was born in Sheffield, Iowa, February 23, 1886. He received his education at Armour Institute of Technology, Chicago, receiving a B. S. degree in 1908 and E. E. in 1911; and at the University of Chicago from which he received the degrees of M. S. and Ph. D. In July, 1914, he joined Bell Telephone Laboratories in New York City. He rapidly achieved distinction in the radio research activities of that organization, and during the World War he was in charge of its radio work. During recent years he has been identified prominently with the investigations of ship-to-shore radio telephone service and of short waves in radio communication. He is recognized as an authority on "fading;" his papers on this phase of radio are distinct contributions to the art. He took a leading part in the transatlantic radio telephone tests in 1923, and for a lecture on this subject received the Fahie Premium from the British Institution of Electrical Engineers. He had twenty inventions pertaining to the radio art to his credit and nine applications are now pending.

Dr. Nichols was a member of the American Institute of Electrical Engineers, the American Mathematical Society, the American Physical Society, the Institute of Radio Engineers, and the Sigma Xi and Eta Kappa Nu fraternities.

His associates in the Bell Telephone Laboratories regard his death as a distinct loss to the profession as well as a great personal loss to themselves. He was a man of pleasing personality; and an efficient and untiring worker, noted for his judgment and insight into all phases of the art of radio.

Orville K. Morris, who joined the Institute only July 24, 1925, died at his home, Highland Park, Michigan, September 7th last. Mr. Morris was born in Marion, Indiana, December 1st, 1875, and, at the time of his death, was associated with the Burroughs Adding Machine Company, Detroit in the capacity of motor inspector and foreman of the electric drive department.

Rush B. Morrow, assistant engineer of the Portland Electric Power Company, died October 6th, 1925. Born at Bryan, Ohio, February 28, 1884, Mr. Morrow's education, after passing through the Bryan High School, was pursued in the Ohio State University, where, in 1903, he started his career in electrical engineering. Upon his graduation from there in 1907, he identified himself with the American Telephone and Telegraph Company of Indianapolis and Cleveland, as equipment man. In 1910 he joined the construction department of the Washington Water Power Company, Spokane, Washington, remaining with them for two years. His next connection was with the Waneta Development Company, Ltd., Spokane, Washington, in 1912. Mr. Morrow served in the World War, first as captain in the Engineering Training Regiment at Camp Humphreys, Va., and, while there, was promoted to major, before going overseas. Upon his return from the service, he joined the Portland Electric Company, with whom in the capacity above stated, he was identified at the time of his death.

A. C. Thomas, telephone engineer for the New York Telephone Company, died suddenly November 6th, 1925. Mr. Thomas joined the Institute in 1901. He was born in Brandon, Vermont, August 24th, 1871, attending public school there and in Cincinnati and Oxford, Ohio. He followed this early education with a one year's college term at the Miami University and later four years' course at the Massachusetts Institute of Technology, from which he graduated with a degree of S. B. in Electrical Engineering in 1893. For four years after graduation he was employed in the engineering department of the New York Telephone Company, in 1898 joining the New York and New Jersey Telephone Company, but returning later to the New York Telephone Company, with whom he remained until his death, November 26th.

Addresses Wanted

A list of names of members whose mail has been returned by the postal authorities is given below, together with the addresses as they now appear on the Institute records. Any member knowing the present address of any of these members is requested to communicate with the Secretary at 33 West 39th St., New York, N. Y.

All members are urged to notify the Institute headquarters promptly of any change in mailing or business address, thus relieving the member of needless annoyance and also assuring the prompt delivery of Institute mail, the accuracy of our mailing records, and the elimination of unnceessary expense for postage and clerical work.

1.—Ezra Adelsberger, 1912 Cold Spring Av., Milwaukee, Wis.
2.—F. E. Bell, U. G. I. Contracting Co., Box 371, Sioux City, Iowa.
3.—Clyde E. Bentley, 2815 Kelsey St., Berkeley, Calif.
4.—Angus Black, 1237 Pacific St., Brooklyn, N. Y.
5.—Paul H. Burkhart, S S S Yale University, 10 Hillhouse Av., New Haven, Conn.
6.—Sidney E. C. Carter, 710½ East 40th St., Los Angeles, Calif.
7.—Geo. B. Coleman, P. O. Box 322, Dayton, Ohio.
8.—Manuel W. Dans, Apt. 6, 519 West 134th St., New York, N. Y.
9.—T. L. Davenport, 2530 May St., Cincinnati, Ohio.
10.—George E. Haines, 3538 W. Monroe St., Chicago, Ill.
11.—Edward C. Hanson, Dixville, Quebec, Canada.
12.—S. Larios, 143 Fourth St., Milwaukee, Wis.
13.—Robert J. Latorre, 1842 Seventh Ave., New York, N. Y.
14.—Louis N. McBane, 1336 Oak St., N. W., Washington, D. C.
15.—Willis E. Osborne, 312 West 4th St., Erie, Pa.
16. Mary Shimanovsky, 24 Mt. Morris Park W., New York, N. Y.
17.—Carl H. Struth, 527 West 124th St., New York, N. Y.

Book Reviews

Popular Research Narratives. A Second Volume:

Engineering Foundation has just collected the second fifty of its Research Narratives and issued them in a book better bound and a little larger than Volume 1. The second volume is illustrated with five portraits of engineer-scientists. It has an introduction by Professor M. I. Pupin, President, American Institute of Electrical Engineers and American Association for the Advancement of Science. The price is one dollar, postpaid. Volume 1 is still obtainable at fifty cents. These brief stories of research, invention and discovery have been well received, widely copied and utilized in many ways. They have carried the gospel of science coupled with the names of the American Societies of Civil, Mining and Metallurgical, Mechanical, and Electrical Engineers into most of the countries of the world. Requests and remittances should be sent to Engineering Foundation, at 29 West 39th Street, New York.

Aeronautical Meteorology; by Willis R. Gregg, U. S. Weather Bureau; Member Contest Committee Nat'l Aeronautic Asso. & American Safety Code Com., Fellow, Am. Meteorological Soc. and Royal Meteorological Soc., 14 pages; cloth binding. $2.50.

This is the first volume of a series of books to be catalogued in the Ronald Aeronautic Library, 15 East 26th Street, New York City. This (and the other volumes to follow) contains practical information on points useful to airmen, with regard to negotiating varying atmospheric conditions, general aeronautical nomenclature and used standards. The text of Aeronautical Meteorology is liberally interspersed with illustrative charts, tables and photographic reproductions to further elucidate and give a concise handbook form of facts of the upper air for purposes of development and safety in this field.

National Directory of Commodity Specifications.

Under this title, the Bureau of Standards of the U. S. Department of Commerce has issued a volume of almost 400 pages, listing about 27,000 items of specifications. No attempt is made in the present volume to give the actual specifications themselves—this will be done later in an "Encyclopedia of Specifications"—but simply to list under the appropriate headings the various organizations having specifications, their date, number, title, etc. Included in the volume is a complete index of about 6,000 products given in the specifications. Not the least of the advantages of the book is the decimal system of classification used; this is based on the source of the material rather than the use of it; The various specifications recommended by Society Committees are included in the complete list as well as those from the American Society of Testing Materials, the American Engineering Standards Committee, and other nation wide organizations. Price $1.25. Address Superintendent of Documents, Government Printing Office, Washington, D. C.

Engineering Societies Library

The library is a cooperative activity of the American Institute of Electrical Engineers, the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Mechanical Engineers. It is administered for these Founder Societies by the United Engineering Society, as a public reference library of engineering and the allied sciences. It contains 150,000 volumes and pamphlets and receives currently most of the important periodicals in its field. It is housed in the Engineering Societies Building, 29 West Thirty-ninth St., New York.

In order to place the resources of the Library at the disposal of those unable to visit it in person, the Library is prepared to furnish lists of references to engineering subjects, copies or translations of articles, and similar assistance. Charges sufficient to cover the cost of this work are made.

The Library maintains a collection of modern technical books which may be rented by members residing in North America. A rental of five cents a day, plus transportation, is charged.

The Director of the Library will gladly give information concerning charges for the various kinds of service to those interested. In asking for information, letters should be made as definite as possible, so that the investigator may understand clearly what is desired.

The library is open from 9 a. m. to 10 p. m. on all week days except holidays throughout the year except during July and August when the hours are 9 a. m. to 5 p. m.

BOOK NOTICES OCT. 1-31, 1925

Unless otherwise specified, books in this list have been presented by the publishers. The Society does not assume responsibility for any statement made; these are taken from the preface or the text of the book.

All books listed may be consulted in the Engineering Societies Library.

Abhandlungen aus dem Aerodynamischen Institut an der Technischen Hochschule Aachen. Heft 4.

Ber., Julius Springer, 1925. 48 pp., diagrs., 11 x 8 in., paper. 5, 10 mk.

Contents:—Strömungserscheinungen in ventilen, by Bruno Eck.—Gastheoretische deutung der Reynoldsschen kennzahl, by Th. v. Karman.—Uber die stabilität der laminarströmung und die theorie der turbulenz, by Th. v. Karman.—Uber einige anwendungen nomographischer methoden in der thermodynamik, by Bruno Eck and Erich Kayser.

These four papers present the results of experimental and mathematical investigations at the Aerodynamic Institute of the Aachen Technical High School.

Aircraft Year Book, 1925.

N. Y., Aeronautical Chamber of Commerce of America, 1925. 316 pp., illus., diagrs., 9 x 6 in., cloth. $5.25.

The Year Book reviews the outstanding events in aviation during 1924, paying particular attention to American happenings, but giving also an account of events abroad. Governmental affairs, air mail service, aerial surveying, commercial operations and technical progress are described; a chronology of events is given; and there is a directory of the various organizations, boards, etc., engaged in aviation.

Alternating-Current Circuits.

By John Myron Bryant, and James A. Correll. N. Y., McGraw-Hill Book Co., 1925. 412 pp., diagrs., tables, 9 x 6 in., cloth. $4.00.

An introductory course in the subject, as given to junior students in electrical engineering at the University of Texas. The first six chapters discuss the theory of a-c. circuits and develop the equations that apply to the various types. The remaining chapters apply these principles to polyphase circuits and transmission lines.

Brown's Directory of American Gas Companies and Gas Engineering and Appliance Catalogue. 1925 Edition.

N. Y., Robbins Publishing Co., Inc., 1925. 1028 pp., illus., 12 x 9 in., cloth. $10.00.

The directory of gas companies furnishes a complete statistical review of the companies supplying manufactured or natural gas. The officials of each company are given, with information on its capitalization, plant capacity, distributing system, output, population served, prices, etc. The prices of gas securities throughout the year 1924 are given, and also financial reports of the principal holding and operating companies. The directory also gives the members of the various public service commissions, a directory of the gas associations and a combined list of their members.

The Catolog presents condensed, carefully indexed catalogs of the manufacturers of supplies and appliances, books, etc.

CHEMICAL ENGINEERING CATALOG. 1925. 10th annual edition. N. Y., Chemical Catalog Co., 1925. 1176 pp., illus., 12 x 9 in., fabrikoid. $10.00.

After ten years of usefulness, the plan and scope of this work have become fairly standardized and only improvements in detail are possible. The book gives chemical engineers, works managers and purchasing agents the information on equipment, supplies and materials which they need frequently, in convenient shape for reference. The new edition lists many additional firms; the catalog of books has been enlarged to include practically all available chemical books in the English language, and the entire catalog has been carefully revised.

CHEMISTRY AND CIVILIZATION.

By Allerton S. Cushman. N. Y., E. P. Dutton & Co., 1925. 171 pp., ports., diagrs., 8 x 6 in., cloth. $2.50.

A new edition of a book that appeared some five years ago. Dr. Cushman has endeavored to present a brief account, in not over-technical language, of what chemistry has done, is doing, and hopes to accomplish in the future for mankind. The present edition is in the main a reprint of the first with corrections but a new chapter, on modern concepts of matter and energy, has been added.

DYKE'S AUTOMOBILE AND GASOLINE ENGINE ENCLOPEDIA.

By A. L. Dyke. 14th edition. Chic., Goodheart-Willcox Co., Inc., 1925. 1233 pp., illus., 10 x 7 in., fabrikoid. $6.00.

The new edition of this work is as remarkable for inclusiveness and for details as its predecessors. It attempts to cover, in one volume, all the matters that may interest the student, repair man or owner, and succeeds in being unusually comprehensive and practical.

Various additions have been made to the text and the illustrations, and the data retained from earlier editions have been revised.

ELECTRICAL ENGINEERING PROBLEMS, Pt. 1; Direct-Current Circuits and Apparatus.

By John G. Pertsch, Jr. N. Y., McGraw-Hill Book Co., 1925. 213 pp., diagrs., tables, 9 x 6 in., cloth. $2.00.

A set of problems on the fundamental relations in electric and magnetic circuits and their application to direct-current machinery, which provides a series of exercises, closely related to engineering practise, for college students.

ELEMENTARY STATISTICAL METHODS.

By William G. Sutcliffe. N. Y., McGraw-Hill Book Co., 1925. 338 pp., diagrs., maps, tables, 9 x 6 in., cloth. $3.00.

A book for college students and others interested in the collection, analysis and presentation of economic statistical data. The treatment is an elementary one, without resort to the use of higher mathematics and is confined principally to the exposition of standard practises in the field.

FUNDAMENTALS OF PHYSICAL CHEMISTRY.

By Arnold Eucken; trans. and adapted from the 2nd German edition by Eric R. Jette and Victor K. La Mer. N. Y., McGraw-Hill Book Co., 1925. (International chemical series). 699 pp., 8 x 6 in., cloth. $5.50.

In spite of the number of excellent books already available, the translators of Professor Eucken's book believe that there is still room for a work in which kinetic theory, thermodynamics and quantum theory, discussed upon the basis of experimental facts, are considered of equal importance for the development of the subject. The book is intended especially for students of chemistry, to whom it introduces the most important points of view and the results of investigations in those branches of modern physics which are closely related to chemistry.

GASOLINE AUTOMOBILE..........v. 4; Fuels and Carburetors.

By P. M. Heldt. Nyack, N. Y., The Author. 1925. 378 pp., illus., diagrs., tables, 9 x 6 in., cloth. $5.00.

This book covers the fuel system of the automobile; that is, the fuel tank and its appurtenances, the strainer, the piping, the feed system, the carburetor, the air cleaner and the fuel itself. These subjects are discussed more fully than is usually done in books on car design.

In the chapters devoted to carburetors, their historical development is sketched and examples of the early types are shown. The theory of the most favored type is outlined and the principles of regulation are explained. The design of carburetor details is discussed and there is a chapter on adjusting. Descriptions of most modern types are given.

Under fuels, the author discusses the different motor fuels available, describing their sources, production, properties, the kinds of carburetors required and the results that the fuels give.

HARVARD BUSINESS REPORTS, v. 1.

Compiled by the Graduate School of Business Administration. Chic. & N. Y., A. W. Shaw Co., 1925. 561 pp., 9 x 6 in., cloth. $7.50.

This is the first volume of a proposed series that will provide a record of business experience which will do for the executive what the law reports do for the lawyer; give him a volume of business precedents which may guide him in executive decisions. The present volume contains 149 cases selected from over 3500 cases collected by the Harvard Graduate School of Business Administration. Each case presents an actual situation which arose in actual business, describes the method adopted by the company to meet the situation and gives the reasons that inspired its selection.

HISTORIC INSTRUMENTS FOR THE ADVANCEMENT OF SCIENCE.

By R. T. Gunther. Lond. & N. Y., Oxford University Press, 1925. 90 pp., illus., 7 x 5 in., cloth. $.85. (Gift of the American Branch).

The collection of ancient scientific instruments at Oxford is one of the best in existence. This little volume, prepared as a guide to the exhibits, describes the astrolabes, orreries, dials, calculating apparatus, surveying instruments and telescopes, and gives incidentally much interesting information on the history of these subjects.

INTERFEROMETER EXPERIMENTS IN ACOUSTICS AND GRAVITATION.

By Carl Barus. Wash., D. C., Carnegie Institution of Washington, 1921-1925. (Publication no. 310) 3 v., diagrs., 10 x 7 in., paper. v. 1 & 3, $2.50 each; v. 2, $1.75.

The investigations carried on by Dr. Barus at Brown University during several years have given many results of interest to physicists, especially to those interested in acoustics and in the constant of gravitation. These three volumes describe in detail the work to date along these lines, as well as the results of many incidental investigations that grew out of the main experiments.

INTRODUCTION TO STATISTICAL METHODS.

By Horace Secrist. N. Y., Macmillan Co., 1925. 584 pp., diagrs., maps, tables, 8 x 5 in., cloth. $2.50.

Intended to provide an introductory textbook which will be also comprehensive and will give a fundamental treatment of the methods of statistical investigation and interpretation. The revised edition has been entirely rewritten, enlarged and rearranged, so that while it retains the distinctive features of its predecessor, it is practically a new book.

DAS KRAFTWERK FORTUNA II.

By Albert Schreiber. Ber. u. Lpz., Walter de Gruyter & Co., 1925. (Siemens-Handbücher, bd. 5) 175 pp., illus., plates, diagrs., 8 x 6 in., cloth 6,50 mk.

This book is one of a series of works issued by Siemens & Halske and the Siemens-Schuckert Works, which deal with various important applications of electricity. The present volume is a description of the new Fortuna power plant near Cologne, one of the newest large plants in Europe.

To describe these works, the author adopts a form intermediate between a monograph and a textbook. The work of construction is traced step by step from the inception of the project, and a complete account of the choice and arrangement of the equipment is given, admirably illustrated by photographs, plans, and diagrams. The result is a description of a modern German electric plant which will interest engineers, students and others.

KURZSCHLUSSTROME BEIM BETRIEB VON GROSSKRAFTWERKEN.

By Reinhold Rüdenberg. Berlin, Julius Springer, 1925. 75 pp., diagrs., 9 x 6 in., paper. 4,80 gm.

This pamphlet discusses the origin of heavy short circuits in power plants and transmission lines, the forms that they take and their effects. The paper is based on experiences of the author and on investigations by him at the Siemens-Schuckert works during many years. It attempts not only to give a qualitative description of these occurrences but also to analyze the procedure mathematically in such a way as to permit a quantitative predetermination of any short circuit phenomena.

LEHRBUCH DER ELEKTROTECHNIK.

By E. Stöckhardt. 3rd edition. Ber. & Lpz., Walter de Gruyter & Co., 1925. 339 pp., illus., diagrs., 9 x 6 in., cloth. 13,-mk.

This work, intended for use as a textbook and for ready reference, is planned to contain within small compass, the information most frequently wanted by a wide circle of electricians. After a brief review of general theoretical principles, the author gives a review of the applications of electricity and then treats of its production and use in chapters on lines and accessories, lighting, magnetism, dynamos, motors, and storage batteries. A final chapter surveys atomic theory, the mercury rectifier and radio communication.

MATERIALS TESTING, THEORY AND PRACTISE.

By Irving H. Cowdrey and Ralph G. Adams. N. Y., John Wiley & Sons, 1925. 129 pp., illus., diagrs., tables, 9 x 6 in., cloth. $1.50.

A small book giving a general survey of its subject and indicating basic methods of attack and interpretation, but not attempting to outline in detail any particular set of tests. It is intended as a text to accompany a laboratory course in the study of materials under stress, rather than as a laboratory manual, and represents the course given by the authors at the Massachusetts Institute of Technology.

MOTION OF ELECTRONS IN GASES . . an address given at the Centenary celebration of the Franklin Institute September, 1924.

By John S. E. Townsend. Lond., Oxford, At the Clarendon Press, 1925. 35 pp., diagrs., 9 x 6 in., paper. $.85. (Gift of Oxford University Press, American Branch).

Professor Townsend's address describes the apparatus used for investigating the motion of electrons through gases and discusses the results that have been obtained. The values for air, nitrogen, oxygen, hydrogen and helium are given.

MOTORSHIPS.

By A. C. Hardy. Lond., Chapman & Hall, 1925. 292 pp., illus., diagrs., 9 x 6 in., cloth. 15s.

The interest of the author is in the revolution in marine propulsion which is being brought about by the internal combustion engine, and his book is an attempt to bring together the various aspects and points of view connected with the fitting of these engines to ships, to comment thereon and to present the various sides of the whole question. Under four headings—construction, arrangement, evolution and operation—the book considers the essentials of the power plant, its arrangement in the ship, the various developments of the main theme, and the effects of the internal combustion engine upon ship construction, etc.

OPTISCHE MESSUNGEN.

By Fritz Löwe. Dresden u. Lpz., Theodor Steinkopff, 1925. (Fortschritte der Chem. technologie in einzeldarstellungen.... bd. 6). 166 pp., illus., 9 x 6 in., paper. 6,-gm.

The series of reports to which this example belongs, is intended primarily to assist German chemists by providing reviews of the advances made since the commencement of the World War. The present monograph on optical measuring will appeal to analysts, physicians and chemists in the metallurgical oil and sugar industries. Its three chapters deal respectively with spectroscopy, refractometry and interferometer methods of measuring. Novel designs of apparatus, new applications and new methods are described, with references to the original publications.

ORGANIC SYNTHESES, vol. 5.

By Carl Shipp Marvel, editor-in-chief. N. Y., John Wiley & Sons, 1925. 110 pp., 9 x 6 in., cloth. $1.50.

This, like preceding volumes of the series, gives detailed directions for the preparation of a number of rare chemical compounds needed in research work, which are not to be had in commerse. Thirty-three compounds are described.

PRACTICAL D. C. ARMATURE WINDING.

By L. Wollison. Lond. & N. Y., Isaac Pitman & Sons, 1925. 228 pp., illus., diagrs., tables, 7 x 5 in., cloth. $2.50.

A practical manual, using only elementary mathematical formulae, and describing methods in detail for all classes of work. Many photographs and unusually clear diagrams illustrate the text.

PRACTICAL TREATISE ON FOURIER'S THEOREM AND HARMONIC ANALYSIS FOR PHYSICISTS AND ENGINEERS.

By Albert Eagle. Lond. & N. Y., Longmans, Green & Co., 1925. 178 pp., 9 x 6 in., cloth. $2.75.

This book is intended "to give a fairly complete account of the practical methods of analyzing any given curve or set of observations into its harmonic constituents, if it be a periodic function, and of detecting any periodic component in it if it be not a periodic function." Only a knowledge of the elements of trigonometry and the calculus is required for understanding it.

STORY OF ELECTRICITY FROM THALES TO EINSTEIN.

By W. F. F. Shearcroft, Lond., Ernest Benn, Ltd., 1925. (Stories of science). 73 pp., diagr., 7 x 5 in., limp cloth. 3s 6d.

A brief non-technical account of the steps by which our knowledge of electricity has advanced. The theories which from time to time have been accepted are given, with an account of the reasons that led to their adoption. Well adapted for those who wish a serious, yet superficial, acquaintance with changing views on the subject.

STRUCTURAL UNITS OF THE MATERIAL UNIVERSE.

By F. W. Aston. (Earl Grey Memorial lecture, no. 7). Lond. & N. Y., Oxford University Press, 1925. 23 pp., illus., diagrs., 9 x 6 in., paper. $.35. (Gift of the American Branch)

An interesting summary of present knowledge of the structure of the atom, written for the general reader.

SUPERHEAT ENGINEERING DATA. 6th edition, revised. N. Y. & Chic., Superheater Co., 1925. 280 pp., illus., diagrs., tables, 7 x 5 in., fabrikoid. $1.00.

This small book, of convenient size for the coat pocket, will be useful to operators of steam power plants. It contains information on the advantages of superheated steam and on the design and performance of superheaters, as well as much frequently needed information on coal and oil fired boilers and on piping. A set of steam tables and a collection of miscellaneous tables are included.

A. S. T. M. TENTATIVE STANDARDS. 1925.

Phila., American Society for Testing Materials, 1925. 876 pp., illus., diagrs., tables, 9 x 6 in., cloth.

Contains 193 tentative specifications, methods of test, definitions of terms and recommended practices; "tentative" being the term used for a standard proposed to the Society, but not yet formally adopted. These tentative standards, however, represent the latest thought on their subjects and are often used for lack of others.

In make-up the volume corresponds to the Book of A. S. T. M. Standards. Its contents cover a wide range of engineering materials, ferrous and non-ferrous metals, cement and clay products, oils, paints, road materials, textiles, etc.

Past Section and Branch Meetings

SECTION MEETINGS

Akron

Inspection trip to Gorge Steam Station and Riverside Substation of the Northern Ohio Traction & Light Co. Mr. L. G. Tighe, Superintendent of Power and Distribution, gave a talk, covering the history of the company. Refreshments were served. October 28. Attendance 120.

Boston

Inspection trip to Montauk Station and to the new substation of the Fall River Electric Light Co. Talks were given by Messrs. G. W. Parks, C. J. Sittinger and J. F. Muir. A buffet supper was served. Joint with A. S. M. E. October 17. Attendance 150.

The Trend of Power Station and Substation Machinery Development, by F. D. Newbury, Westinghouse Electric & Manufacturing Co. November 10. Attendance 130.

Chicago

Mechanical Features of the Chicago Union Station, by Edison Brock, Chicago Union Station Co., and

Electrical Features of the Chicago Union Station, by C. W. Post, Chicago Union Station Co. October 5. Attendance 200.

Cincinnati

A Knowledge of Mazda Lamps, by E. A. Snyder, Westinghouse Lamp Works. Motion pictures. October 13. Attendance 90.

Connecticut

An Aeroplane Trip Over Europe, by C. M. Ripley, General Electric Co. October 28. Attendance 60.

Industrial Heating, by C. L. Ipsen, General Electric Co. Illustrated. Refreshments were served. November 3. Attendance 100.

Lightning, by F. W. Peek, Jr., General Electric Co. Illustrated. November 9. Attendance 100.

Denver

The New Plant of the Ideal Cement Company, by Paul C. Van Zandt. A dinner preceded the meeting. October 16. Attendance 40.

The Girand Case, by L. Ward Bannister, Denver Chamber of Commerce. Luncheon Meeting. Joint with Colorado Engineering Council. November 10. Attendance 125.

Detroit-Ann Arbor

Research, by C. F. Kettering, General Motors Corp. October 13. Attendance 150.

Things Electrical, by S. M. Dean, Detroit Edison Co. The speaker illustrated by means of mechanical models some of the difficulties encountered in operating a large transmission network. Motion picture was shown. A dinner preceded the meeting. November 3. Attendance 250.

Erie

Ship Stabilizers and Compasses, by R. B. Lea, Sperry Gyroscope Co. Illustrated with models, slides and motion pictures. October 20. Attendance 205.

Fort Wayne

European Industrial Conditions, by W. S. Goll, General Electric Co. Motion pictures. October 8. Attendance 50.

Kansas City

Industrial Lighting, by A. S. Turner, Edison Mazda Lamp Works. Joint with A. S. M. E. October 5. Attendance 83.

Carrier-Current Telephony as Applied to Transmission Lines, by G. C. Schadd, Kansas University. Illustrated, and

Super-Synchronous Motor, by M. M. Boggess, General Electric Co. November 9. Attendance 61.

Los Angeles

Scientific Education, by R. W. Sorensen, California Institute of Technology,

Evolution of the Fire-Alarm System, by R. H. Manahan, City Electrician, and

The New Fire-Alarm System for the City of Los Angeles, by Lewis Degen, Consulting Electrical Signal Engineer. The new fire-alarm central station was inspected. A dinner preceded the meeting. November 3. Attendance 179.

Lynn

The Laughter Barrage, by Frank G. Armitage. Social Meeting. Refreshments were served. October 28. Attendance 130.

Transmission of Pictures over Telephone Lines, by A. B. Clark, American Telephone & Telegraph Co. Illustrated. November 10. Attendance 187.

Minnesota

Conditions that Make Rural Electrification a Success in the Middle West, by E. A. Stewart, University of Minnesota. Illustrated with motion pictures. November 2. Attendance 50.

Niagara Frontier

Automatic Stations, by Chester Lichtenberg, General Electric Co. A model equipment was used for demonstration. Motion pictures. October 9. Attendance 39.

Philadelphia

Radio, A Branch of Electrical Engineering, by R. S. Kruse, American Radio Relay League. October 12. Attendance 125.

The Insulating Value of Wood Crossarms and Poles, by A. O. Austin, Ohio Brass Co. November 9. Attendance 125.

Pittsburgh

Motor-Generator Locomotives and Railway Electrification, by N. W. Storer, Westinghouse Electric & Mfg.Co. Illustrated with slides. September 14. Attendance 287.

Better Engineers—Do We Need Them and Can We Get Them, by W. E. Wickenden, Society for the Promotion of Engineering Education. Illustrated. October 12. Attendance 131.

Power Flow in Electrical Machinery, by Joseph Slepian, Westinghouse Elec. & Mfg. Co. November 10. Attendance 276.

Pittsfield

Inspection trip to Whitingham Dam, the Power House at Surge Tank and the automatic substation at Searsburg. Luncheon was served. October 12. Attendance 180.

Trip Through Europe, by G. Faccioli, General Electric Co. Chief among the things mentioned were the debates in the International Conference on High Voltage Systems. November 3. Attendance 690.

Time Lag of Needle Gap, the Dufour Cathode-Ray Oscillograph and the Lichtenberg Camera, by K. B. McEachron and E. J. Wade, General Electric Co. November 10. Attendance 40.

Portland

Electricity in the Manufacture of Paper, by C. W. Fick, General Electric Co. Slides and motion pictures. Refreshments were served. October 14. Attendance 86.

Providence

A Comparison of the Modern Stoker with the Pulverizing System of Burning Coal, by H. S. Colby, Riley Stoker Cor.p Illustrated. Joint meeting with Power Section of Providence Engineering Society. October 27. Attendance 75.

Seattle

The Utilization of Electrical Energy in the Manufacture of Paper, by C. W. Fick, General Electric Co. Illustrated with charts, slides and motion pictures. October 21. Attendance 57.

Spokane

Development of the Electric Refrigeration Industry and Its Relation to Central Stations, by C. L. Lewis, Electro-Kold Corp. October 23. Attendance 22.

Springfield

Automatic Train Control, by W. H. Reichard, General Railway Signal Co. Illustrated. October 27. Attendance 76.

Toledo

Artificial Light and Civilization, by M. Luckiesh, National Lamp Works, of G. E. Co. October 28. Attendance 175.

Toronto

Lightning Arresters—What They Do and How They Do It, by K. B. McEachron, General Electric Co. The speaker also described the cathode-ray oscillograph and showed slides of 200,000,000-cycle oscillograms. October 9. Attendance 120.

Distribution Transformers Under Changing Load Conditions, by G. A. Brace, Canadian General Electric Co. October 30. Attendance 80.

Urbana

Recent Developments in the Public Utility Field, by Professor E. B. Paine, University of Illinois. October 21. Attendance 52.

Vancouver

Power-Factor Correction, by R. L. Hall, British Columbia Electric Railway Co. November 3. Attendance 55.

Washington

Modern Power-Plant Design, by V. E. Alden, Consolidated Gas and Electric Co. Dinner preceded the meeting. October 13. Attendance 210.

Electricity in Submarines, by Lieutenant-Commander E. W. Burrough, United States Navy, and

Notes on Underground Conductors, by T. M. Roberts, Unitep States Navy. Refreshments were served. November 10. Attendance 126.

BRANCH MEETINGS

Alabama Polytechnic Institute

Bell Telephone System, by J. A. Douglas, Alabama Polytechnic Institute. October 14. Attendance 15.

Carrier-Current System, by J. Malcolm Wilder, student. October 21. Attendance 31.

Technical Education, by Professor Hill. October 27. Attendance 37.

Social meeting with entertainment. November 4. Attendance 30.

University of Arizona

Electrical Mine Haulage, by Edward Brooks. The following officers were elected: Vice-President, George Diamos; Secretary-Treasurer, J. W. Cruse. September 26. Attendance 29.

Automatic Substations, by W. R. Brownlee, and

Early Electrical History, by J. W. Cruse. October 3. Attendance 13.

Automobile Lighting, by Jos. A. Denzer, and

Cottrell Plants, by T. E. Davis. October 10. Attendance 14.

Roosevelt Dam, by D. M. Dexter. Picture, entitled "White Coal" was shown. October 17. Attendance 17.

Artificial Lightning, by J. D. Williams. Picture, entitled "The Telephone" was shown. October 24. Attendance 15.

The Colorado River Pact, by W. T. Wishart, and

Archery, by Oliver Wright. October 31. Attendance 14.

University of Arkansas

Business Meeting. October 6. Attendance 17.

Benefits Derived from A. I. E. E., by Professor W. B. Stelzner. October 20. Attendance 45.

Armour Institute of Technology

Business Meeting. The following officers were elected: Chairman, H. J. Prebensen; Treasurer, A. S. Hansen; Secretary, W. A. Dean, Jr., May 7. Attendance 28.

Business Meeting. October 1. Attendance 28.

Investigations and Reports, by W. G. Bailey, Business Research Corp. October 15. Attendance 29.

Mail-Handling System of the Post Office, by S. F. Henderson, student, and

Outside Construction for Illinois Bell Telephone Company, by F. E. Wilson, student. November 5. Attendance 25.

Brooklyn Polytechnic Institute

Surveying as Used in Electrical Engineering, by G. F. Marks, student. Refreshments were served. October 29. Attendance 26.

Bucknell University

Benefits of Electrical Engineering and Membership in the A. I. E. E. by Professor W. K. Rhodes. October 12. Attendance 23.

California Institute of Technology

The Niagara Falls Power Plants, by W. A. Lewis. October 9. Attendance 30.

Safety-Switchboard Design and Construction, by L. J. Wells, Safety Electric Products Co. October 23. Attendance 40.

Applications of the Vacuum Tube in Telephone Work, by A. S. Rose, American Telephone & Telegraph Co. Refreshments were served. October 29. Attendance 54.

University of California

Buildings and Grounds of the Campus, by Dean Woods. Joint meeting with A. S. M. E. September 2. Attendance 47.

The Meaning of the A. I. E. E., by Mr. Howe. September 29. Attendance 85.

The Klydonograph, by P. B. Garrett, Westinghouse Elec. & Mfg. Co. Illustrated with slides. October 21. Attendance 40.

Carnegie Institute of Technology

The Relationship between the Pittsburgh Section and the Carnegie Institute of Technology Branch, by G. F. Humphrey. A short talk was also given by Professor Dennison. October 14. Attendance 37.

The Fynn-Weichsel Motor, by Mr. Cunnings, Wagner Electric Corp. A moving picture, entitled "Temperature and Motor Endurance," was shown. November 4. Attendance 34.

Catholic University of America

Business Meeting. The following officers were elected: President, B. J. Kroeger; Vice-President, W. S. Sparks; Secretary, J. E. O'Brien; Treasurer, E. J. Twomey. September 28. Attendance 13.

Benefits Derived from Membership in the A. I. E. E., by Professor T. J. MacKavanaugh. October 21. Attendance 15.

University of Cincinnati

The Miami Fort Generating Station by J. R. Hartman, Union Gas and Electric Co. October 8. Attendance 160.

Miami-Fort-Cincinnati 66,000-Volt Transmission Line, by O. S. Clark, Union Gas and Electric Co. October 22. Attendance 40.

Colorado Agricultural College

Business Meeting. The following officers were elected: President, C. O. Nelson. Vice-President, B. Johnson; Secretary-Treasurer, Duane Asay. October 5. Attendance 15.

University of Colorado

Talks on the A. I. E. E. were given by Professors W. C. DuVall and M. S. Coover. October 14. Attendance 51.

Electrical Engineering in the Reclamation Service, by H. H. Plumb, Bureau of Reclamation. November 4. Attendance 50.

University of Denver

Business Meeting. October 28. Attendance 16.

Drexel Institute

Get-Together Meeting. October 2. Attendance 18.

Electrical Features of Richmond Station, by F. R. Ford, Philadelphia Electric Co. Illustrated with slides. October 23. Attendance 45.

University of Florida

A-C. and D-C. Underground Network Distribution Systems, by F. W. L. Hill, Electric Bond and Share Co. The following officers were elected: Chairman, O. B. Turbyfill; Vice-Chairman, W. H. Stanwix-Hay; Secretary, R. Theo. Lundy. October 12. Attendance 25.

University of Idaho

Business Meeting. October 13. Attendance 11.

Iowa State College

Recent Developments in Telephone Communication, by Dr. Perrine, American Telephone & Telegraph laboratories. October 21. Attendance 210.

State University of Iowa

Electrical Propulsion of Ships, by L. M. Bates, and

Manufacture of Aluminum by Electricity, by E. L. Beers. October 21. Attendance 46.

The New University Power Plant, by L. H. Brown, and

Engineering Aboard a Steamer, by G. Gangadharan. October 28. Attendance 43.

Checking Magnetic Permeability of Iron, by H. Cook,

Electric Furnaces, by James Fox, and

Sir Adam Beck's Answer to Samuel S. Wyer's Report, by Roger Knight. November 4. Attendance 45.

Kansas State College

My Summer Work with Westinghouse, by E. L. Long, student. October 12. Attendance 74.

Relay Testing, by Mr. Bueshe. October 26. Attendance 78.

My Summer Work with the Utah Power and Light Company, by E. J. Weeks. November 9. Attendance 72.

University of Kansas

Get-Together Meeting. Refreshments were served. September 24. Attendance 131.

Motion picture entitled "White Coal" was shown. October 8. Attendance 63.

Social Meeting of all Engineering Societies. Refreshments were served. October 21. Attendance 114.

Recent Developments in Electrical Engineering, by George Fiske, General Electric Co. Illustrated. November 5. Attendance 50.

Lafayette College

Inspection trip to Nazareth Cement Company. October 29. Attendance 29.

Interconnections of Transmission Lines and Super-Power, by R. B. Hayes, Westinghouse Electric & Mfg. Co. Illustrated with slides. November 10. Attendance 30.

Choosing a Vocation, by J. R. Mills, Bell System Laboratories, Inc. Joint meeting with A. S. C. E., A. S. M. E. and John Markle Mining Society. November 12. Attendance 210.

Lehigh University

What an Engineering Graduate is Up Against, and How to Meet It, by Farley Osgood, Consulting Engineer. Refreshments were served. October 15. Attendance 77.

Massachusetts Institute of Technology

Power Possibilities of the Niagara and St. Lawrence Rivers, by H. B. Dwight. October 16. Attendance 35.

Inspection trip to "L" Street Station of the Boston Edison Company. October 28. Attendance 24.

What Every Engineer Must Sometime Do, by E. S. Lee, General Electric Co. November 13. Attendance 32.

Michigan State College

The Development of the Electrical Industry in Michigan, by Professor M. M. Cory,

What is Expected of an Electrical Engineer Along Social Lines, by Mr. Foltz.

My Experiences with Several Student Branches, by Mr. Naetor. October 9. Attendance 18.

Public Lighting Systems and Their Development in Detroit, by J. Menmuir, student. Refreshments were served. October 27. Attendance 26.

University of Michigan

Things Electrical, by S. M. Dean, The Detroit Edison Company. This meeting was held by the Detroit-Ann Arbor Section. November 3. Attendance 16.

Missouri School of Mines and Metallurgy

Business Meeting. The following officers were elected: President, W. J. Moulder, Secretary-Treasurer, R. P. Baumgartner. October 14. Attendance 8.

University of Missouri

Outline of Aims and Purposes of the A. I. E. E., by Professor M. P. Weinbach. Motion pictures on "The Wizardy of Wireless" were shown. The following officers were elected: Chairman, Professor M. P. Weinbach; Vice-Chairman, A. B. Glover, Secretary, L. Spraragen; Assistant Secretary, J. A. Logan; Treasurer, M. W. Levy. October 5. Attendance 27.

Talks on "Summer Work" were given by students. October 19. Attendance 25.

Montana State College

Gas-Electric Car, by Paul Forrest,

Railway Electrification, by Clarence Kerlee, and

Japanese Electrification of State Railways, by Thomas Heal. October 26. Attendance 150.

Splicing Wires and Cables, by R. B. Hannah. Demonstration and lecture. A banquet preceded the meeting. November 2. Attendance 150.

University of Nebraska

Business Meeting. Mr. Ralph Worrest was elected President. October 9. Attendance 22.

College of the City of New York

Business Meeting. October 15. Attendance 10.

Inspection Trip to Audubon Exchange of the New York Telephone Company. October 21. Attendance 18.

Inspection Trip to the Edgecombe and Bradhurst Exchanges of the New York Telephone Co. October 28. Attendance 10.

Railway-Signal Operation, by D. Schneeweiss, student. November 5. Attendance 15.

North Carolina State College

Business Meeting. October 6. Attendance 45.

Development of the Electric Light Industry and the Public Service Company, by J. V. Strange, Carolina Power and Light Co. A banquet preceded the meeting. October 20. Attendance 65.

University of North Carolina

The Flat River Hydro-Electric Development, by S. W. Reese, student. October 23. Attendance 29.

The Salient Features of the Southern Power Company, by H. J. Wheeler. November 5.

University of North Dakota

Tesla-Coil Experiments, by H. Polsfut, student, and

Advantages of Student Membership in the A. I. E. E., by Professor D. R. Jenkins. October 5. Attendance 27.

The National A. I. E. E., by Vernon Hauck, student,

Aims of Our Local Branch for the Coming Year, by George Russ, student,

Developments of Science in the Last Century, by Arthur Eielson, student, and

Karapetoff's View of Success Through Threads of Activity, by L. J. Lunas. October 19. Attendance 28.

The Heaviside Theory, by J. A. Hutcheson, student,

Putting It Across, by Herbert Tellman, student, and

Bus Transportation, by Alfred Botten, student. November 2. Attendance 29.

University of Notre Dame

Power Sales and Its Relation to Industry, by S. M. Caldwell, Indiana and Michigan Electric Co.,

The Development of Electricity, by Stanley Boyle, student, and

The History of the Dynamo, by Narbin Arehart, student. October 19. Attendance 48.

Ohio Northern University

Electrification of Railroads, by Mr. Herman, and

Metering Panels, by Mr. Roth. November 5. Attendance 26.

Ohio State University

Business Meeting. October 9. Attendance 61.

Social Meeting. November 6. Refreshments were served. Attendance 280.

Oregon Agricultural College

Get-Together Meeting. Refreshments were served. October 23. Attendance 150.

Pennsylvania State College

Business Meeting. October 22. Attendance 30.

University of Pennsylvania

Business Meeting. October 6. Attendance 57.

Business Meeting. November 4. Attendance 46.

University of Pittsburgh

Problems in Super-Power Developments, by J. S. Humphries, West Penn Power Co. October 2. Attendance 34.

Current Events, by F. E. McTaggart, student,

Cooperative Work with Bell Telephone Company, by L. B. Biebel, student, and

Electrification of the Iron Industry, by A. L. Plette, student. October 16. Attendance 33.

Ventilation of the Liberty Tubes, by S. A. Swetonic, student,

Turbo Generators, by G. E. Marshall, student, and

Carrier Telephone Systems, by L. M. Brush, student. October 23. Attendance 27.

My Experiences in the Engineering Field, by E. A. Casey. October 30. Attendance 32.

Purdue University

Future Plans for Electrical Engineering at Purdue, by Professor C. F. Harding, and

Some Summer Experiences, by Professor D. D. Rowell. The speaker explained the inductive and hazard tests conducted by the Michigan Bell Telephone Company. Refreshments were served. October 20. Attendance 80.

Rhode Island State College

A Study of the Time Lag of the Needle Gap, by K. B. McEachron and E. J. Wade, General Electric Co. October 9. Attendance 17.

A motion picture, entitled "Electrified Travelogue," was shown. October 23. Attendance 24.

Radio, by H. Hopkins and B. Taylor. November 6. Attendance 13.

Rose Polytechnic Institute

Dresser Power Plant, Mechanical Equipment, by R. W. Taky, and

Dresser Power Plant, Electrical Equipment, by B. G. Witty. October 28. Attendance 18.

Inspection trip to the Dresser Power Plant. November 4. Attendance 20.

Rutgers University

Rural Electrification, by H. S. Allen, and

Questions and Answers on Rural Electrification, by S. D. White. Remarks were added by Professor Thompson. November 9. Attendance 21.

South Dakota School of Mines

Social Meeting. Film on "Power" was shown. October 19. Attendance 114.

University of Southern California

Business Meeting. September 24. Attendance 25.

Business Meeting. October 15. Attendance 23.

Business Meeting. November 5. Attendance 29.

Stanford University

Business Meeting. October 13. Attendance 12.

Some Developments in Telephone Transmission and Operation, by A. F. Rose, American Telephone & Telegraph Co. Illustrated with slides. November 3. Attendance 25.

University of Tennessee

Business Meeting. October 8. Attendance 16.

Report on Water Power Trip, by H. B. Shultz, student, and

The Tesla Coil, by F. N. Green, student. October 22. Attendance 32.

Texas Agricultural & Mechanical College

Business Meeting. The following officers were elected: President, L. H. Cardwell; Vice-President, G. B. Manning; Secretary, C. A. Altenbern. October 23. Attendance 99.

Educationsl Courses and Scope of Work at the Westinghouse Plant at East Pittsburgh, by C. C. Yates, and

The Plant of the General Electric Company at Schenectady, the Opportunities Offered to Graduates and the Work Being Done by College Men, by R. P. Ward. November 6. Attendance 82.

University of Utah

Business Meeting. The following officers were elected: Chairman, F. C. Bates; Vice-Chairman, M. L. Saunders; Secretary-Treasurer, Charles E. Hoffman. October 27. Attendance 8.

Virginia Military Institute

The Stirlington Power Station of the Louisiana Power Company, by J. O. Couch, and

Electric-Drive Possibilities for Railless Self-Propelled Vehicles, by C. P. Mabie. October 14. Attendance 20.

Electricity in the Coal Fields, by E. T. Morris. Illustrated with slides. November 2. Attendance 22.

Virginia Polytechnic Institute

Life and Work of Rowland, by F. L. Robeson. October 22. Attendance 20.

Tuning the Wireless, by T. A. Keck,

The Life of George Westinghouse, by George Rotenberry, and

The Importance of Electricity, by Mr. Webb. November 4. Attendance 25.

Illumination, by V. D. Wheeldon, Rumsey Electric Company, J. G. Herringer, Astoria Lamp Division, and E. L. Scholl, Holophane Glass Company. November 6. Attendance 200.

University of Virginia

Business Meeting. Motion pictures were shown. October 26. Attendance 18.

State College of Washington

Business Meeting. October 8. Attendance 68.

Washington University

Business Meeting. October 12. Attendance 11.

The Electrical Business, by Mr. Haege, Wesco Electrical Supply Co. Refreshments were served. November 3. Attendance 19.

Business Meeting. November 12. Attendance 23.

University of Washington

Te Baker River Development, by W. D. Shannon, Puget Sound Light and Power Co. Illustrated with slides. The speaker also spoke on Choosing a Profession. October 13. Attendance 36.

West Virginia University

Installation of a 66-Kv. Underground Cable, by R. W. Beardslee,

Educational Program of Westinghouse, by J. U. Neill,

Piedmont and Northern Railway System, by H. S. Muller,

A Broadcasting Station Seen from the Inside, by W. F. Davis,

Fuse Boxes, by R. G. Calvin,

Future of Electric Railways, by E. H. Braid,

Report of Work with S. R. C., by I. L. Smith,

Trip Through Substation, by A. L. P. Smeichel,

Life of Professor Hazeltine, by B. R. Shafer, and

Iron in Radio Transformers, by E. L. Smith. October 19. Attendance 32.

Gas-Electric Cars and Deisel Locomotives, by C. Pike,

Selection and Maintenance of Oil Circuit Breakers, by W. L. Nuhfer,

Electric Locomotive of 7125 H.P. by G. R. Latham,

Radio Central's Wireless Transmitting Station, by W. E. Vallines,

The Engineer and His Practical Relation to Our Everyday Life, by W. A. Williams,

Submarine Conduit Lines, by A. M. Kalo,

Invisible Police Alarm, by H. S. McGowan,

Virginia Railroad, by J. L. Kessinger,

Life of Lord Kelvin, by E. R. Long,

Belt Conveyer at Ellis Mine, by C. W. Moore,

Electric Railways, by James Criechi, and

Automatic Hydroelectric Station, by E. A. Berry. October 26. Attendance 36.

Electrical Rail Operation in 1925, by K. D. Stewart,

The Gas-Electric Railway Car, by W. W. Reed,

The Wadson Motor Check, by D. S. T. Roush,

Signal Lighting, by D. A. Akins,

Condition of Electrical Aparatus After a Flood, by J. W. Schramm,

Parkersburg Power Plant, by R. C. Cole,

Benefits of Interconnection, by R. A. Osborne,

Power Development of Virginia Railway, by G. H. Cornell,

Gasoline-Electric Cars for Branch Lines, by C. B. Binns, and

Self-Propelled Electric Vehicles, by Mr. Shobe. November 2. Attendance 32.

Automatic Substation and Steel Works, by R. W. Beardslee

Electricity from the Wind, by A. M. Kalo,

Disc-Type Thermal Switch, by H. S. Muller,

High-Tension Insulation, by C. M. Borror,

Gas Electric Cars, by A. L. Schmeichel,

Insulation Oils for Circuit Breakers, by B. R. Shafer,

Coolidge X-Ray Tube, by I. L. Smith,

Automatic Substations, by E. H. Braid,

Land Slide in Jackson Hole District, by L. S. Davis, and

Operation of Electric Railways in America, by G. E. Meintell. November 9. Attendance 36.

University of Wisconsin

Motion pictures of the Panama Canal construction were shown. October 20. Attendance 65.

Engineering Societies Employment Service

Under joint management of the national societies of Civil, Mining, Mechanical and Electrical Engineers cooperating with the Western Society of Engineers. The service is available only to their membership, and is maintained as a cooperative bureau by contributions from the societies and their individual members who are directly benefited.

Offices:—33 West 39th St., New York, N. Y.,—W. V. Brown, Manager.
53 West Jackson Blv'de., Room 1736, Chicago, Ill., A. K. Krauser, Manager.

MEN AVAILABLE.—Brief announcements will be published without charge but will not be repeated except upon requests received after an interval of one month. Names and records will remain in the active files of the bureau for a period of three months and are renewable upon request. Notices for this Department should be addressed to ***EMPLOYMENT SERVICE, 33 West 39th Street, New York City,*** *and should be received prior to the 15th of the month.*

OPPORTUNITIES.—A Bulletin of engineering positions available is published weekly and is available to members of the Societies concerned at a subscription rate of $3 per quarter, or $10 per annum, payable in advance. Positions not filled promptly as a result of publication in the Bulletin may be announced herein, as formerly.

VOLUNTARY CONTRIBUTIONS.—Members obtaining positions through the medium of this service are invited to cooperate with the Societies in the financing of the work by nominal contributions made within thirty days after placement, on the basis of $10 for all positions paying a salary of $2000 or less per annum; $10 plus one per cent of all amounts in excess of $2000 per annum; temporary positions (of one month or less) three per cent of total salary received. The income contributed by the members, together with the finances appropriated by the four societies named above, will it is hoped, be sufficient not only to maintain, but to increase and extend the service.

REPLIES TO ANNOUNCEMENTS.—Replies to announcements published herein or in the Bulletin, should be addressed to the key number indicated in each case, with a two cent stamp attached for reforwarding, and forwarded to the Employment Service as above. Replies received by the bureau after the positions to which they refer have been filled will not be forwarded.

POSITIONS OPEN

SALES ENGINEER, of exceptional ability wanted to represent manufacturer of battery charging equipment. Salary and commission. Apply by letter with full details. Location, Middlewest. R-7636.

RECENT GRADUATE, electrical engineer for general radio work. Knowledge of telegraph code desirable. Must be American citizen. Salary depends on experience and includes board and lodging. Headquarters, New York. R-7796

MEN AVAILABLE

1925 ELECTRICAL ENGINEERING GRADUATE, wishes opportunity to obtain experience in manufacturing, public service, or contracting. Available after one weeks notice. Will go anywhere. C-348.

TECHNICAL GRADUATE, age 24, single, graduate B. E. S. '22, experience consists of telephone test with Western Electric, some armature and stator winding, and about two years in meter work, both single phase and power meters. Would like position in automatic substation construction, or would consider power meter work. Location immaterial. B-7464.

ELECTRICAL ENGINEER, age 25, single, graduate of M. I. T., two and one-half years of power plant operation, design and construction experience. Desires position with construction company. Would consider South America or other foreign position. Available on three weeks' notice. B-7038.

ELECTRICAL ENGINEER, age 28, single, graduate E. E. and A. B., three years' experience in electrical installation work in South America and Mexico. Speaks Spanish and French fluently. Available in three weeks. Location anywhere. C-94.

ELECTRICAL AND VALUATION ENGINEER, age 32, single, good working knowledge of Spanish. Ten years' practical experience installation, operation of steam and hydroelectric plants, electric mining, industrial and public utility equipment, including two years General Electric Company's tests, two years with Public Service Commission of New York State. Now specializing in inventories, appraisals, property reports, investigations, classified accounting systems for public utilities, mining and industrial corporations. Salary $300 per month. B-9636.

ENGINEER, Member A. I. E. E. 15 years, technical and commercial experience, former head of technical-literary department of large European manufacturing concern asks technical, commercial and scientific translation work in all principal languages. B-8609.

1921 GRADUATE ELECTRICAL ENGINEER desires position with public utility, consulting engineer or research. Experience covers manufacture of hydroelectric power stations. Two years design on switchboards, power stations, transmission lines and substations. One year as telephone equipment engineer specializing on power equipment and control. Available 30 days after agreement. B-8634.

ELECTRICAL MECHANICAL SUPERINTENDENT, age 42, married, 23 years' experience in the installation and maintenance of electrical equipment of public utility power plants and substations, and the electrical and mechanical equipment of industrial plants. Details on request. Available on reasonable notice. Location, Eastern States preferred. B-721.

ELECTRICAL DESIGNING ENGINEER, age 45, technical graduate, 20 years' experience with manufacturing, construction, and public utility companies. Broad experience on electrical apparatus, power plants, high tension, indoor and outdoor substations, and distribution systems. Desires a permanent position in similar capacity. Married. C-581.

SALES ENGINEER, Specialist in high voltage equipment; switchgear, transmission conductors and insulators, transformers, arresters. University graduate, very extensive experience in teaching, research, design, advertising and sales. Westinghouse and General Electric training. Pacific Coast preferred but will go anywhere. No objection to traveling. Minimum salary $4000. Available December 1. C-577.

ELECTRICAL ENGINEERING GRADUATE, age 24, having a thorough knowledge of patent law and procedure, two and one-half years' experience as examiner in the patent office, two years of legal training, desires position with an electrical manufacturing company, or with patent attorney handling many electrical applications. Middlewest preferred. C-610.

GRADUATE ELECTRICAL ENGINEER, ten years' experience in charge of maintenance, operation and construction for large industrial companies. Several years' valuation and public service commission work. Desires responsible position with good company. Florida or Missouri preferred. Available on one month's notice. B-1693.

ELECTRICAL ENGINEER, university graduate, age 31, inventor, familiar with physics and higher mathematics. Four years' radio laboratory and factory experience, fourteen months in public utilities and cable manufacturing. Able to produce results. Now employed but wishes change. Desires connection with public utility, radio or electrical concern. Available on short notice. B-7178.

ELECTRICAL ENGINEER, M. E., at present executive in development of accounting machinery, seeks opening in New York District about January 1st. Twenty years in invention, design and manufacture of electrical apparatus and mechanical devices. Experienced in telephone, telegraph, radio, marine and other lines. Also retail business. B-5948.

ENGINEERING EXECUTIVE will soon resign position as steel mill electrical superintendent with successful record in both electrical and mechanical experience and responsibility. Technical graduate, G. E. test, construction, sales engineering, organization and operation. Effective in practical analysis and solution industrial problems. Desires consultant or managerial position. Available for interview. C-615.

ELECTRICAL ENGINEER, age 39, married, experienced in industrial lighting and power, including motor installations, illumination systems, overhead and underground distribution systems, transformer stations, industrial power plant electrical equipment, etc. Prefers connection with industrial operating string of plants, or with consulting firm engaged in industrial work. Prefer Middle or Southwest. Salary dependent on location and nature of work. B-9772.

ELECTRICAL ENGINEER AND BUSINESS ADMINISTRATION GRADUATE, age 34, desires position as electrical engineer or assistant manager with large public utility. Twelve years' experience design and operation of generating stations, substations, transmission systems, eight years with large public utility, four with steel and oil industrial corporations. Expert on preparing budgets, design plans, estimates, writing specifications, reports. Recent extensive experience on automatic substations and supervisory control. C-635.

MEMBERSHIP — Applications, Elections, Transfers, Etc.

ASSOCIATES ELECTED NOVEMBER 24, 1925

ANDERSON, RALPH P., Electrical Operator, The Washington Water Power Co., Spokane, Wash.
BARNARD, MARTHINUS CHRISTOFFEL, 106A Transvaal Road, Kimberley, Cape Province, So. Africa.
BAUGHN, EARL, Draftsman, The Washington Water Power Co., Spokane, Wash.
BETZ, CHARLES A., Electrician, The Ohio Power Company, Newcomerstown, Ohio.
BRICE, GEORGE WALLACE, Chief Equipment Man, American Tel. & Tel. Co., Key West, Fla.
BROWNE, DOMINICK JOSEPH, Jr., Central Office Man, Bell Telephone Co. of Penna., 1080 Fifth Ave., New Kensington, Pa.
BURBANK, EDWARD W., District Manager, Allis-Chalmers Mfg. Co., 1415 Sante Fe Bldg., Dallas, Texas.
CHOMEAU, HENRI, Jr., Inspector. Electric Storage Battery Co., 1058 S. Vandeventer Ave., St. Louis, Mo.
COOPER, SAMUEL JAMES, Engineer, Central Control Office, Marconi Co., Montreal, P. Q., Canada.
CRISTAL, CHARLES WOLFORD, Draftsman, Elec. Dept., Cleveland Union Terminals Co., 1106 Ulmer Bldg., Cleveland, Ohio.
CURREY, WALTER C., Asst. Engineer in charge of Tests, Interborough Rapid Transit Co., 147th St. & 7th Ave., New York; res., Pleasantville, N. Y.
*DANIEL, LAURENCE HANDY, Manager, Industrial Engineering Corp., O'Reilly 104, Havana, Cuba.
*DAVE, SHRI-KRISHNA B., Chief Engineer, Bhaunagar Electric Supply Co., Bhaunagar; for mail, Baramati, India.
DAVIS, HAROLD JEROME, Chief Electrician, Port of Portland Drydocks, Portland, Ore.
DaVOLIO, JOSEPH MATTHEW, Electrical Engineer, 171-175 Cherry St., New York, N. Y.
DE SANTIS, JULIUS, 1659 W. 11th St., Brooklyn, N. Y.
DIETZE, IRWIN CHARLES, Senior Topographical Draftsman, Dept. of Water & Power, Bureau of Power & Light, City of Los Angeles, 207 So. Broadway, Los Angeles, Calif.
DODD, JOHN HAINSWORTH, Asst. Power Plant Engineer, Broken Hill Associated Smelters, Port Pirie, South Australia.
EDELEN, HUGHES W., General Commercial Agent, The Pacific Tel. & Tel. Co., 1616 Coast Division Bldg., 140 New Montgomery St., San Francisco, Calif.
EICHER, FRANK C., Electrician, Edward Ford Plate Glass Co., Rossford; res., Toledo, Ohio.
ELLIS, WALTER JESSE, Jr., Chief Operator, The Ohio Power Co., Canton, Ohio.
FOWLER, ALAN, Erection Engineer, Hydro-Electric Power Commission, 190 University Ave., Toronto; for mail, Hydro, Ont., Can.
FOWLER, ALEXANDER DANIEL, Junior Engineer, U. S. Engineer Office, Florence, Ala.
FRANK, ERNEST, Electrical Designer, New York Edison Co., 44 East 23rd St., New York, N. Y.
FREEMAN, OSCAR M., Technical Clerk, The New York Edison Co., 327 Rider Ave., New York, N. Y.
GAISMAN, AIME, Purchasing Agent & Chief Salesman, Tampico Electric Co., Tampico, Tamps., Mexico.
GEORGE, NILS NILSSON, Elec. Dept., Twin City Rapid Transit Co., Snelling & University Ave., St. Paul, Minn.
GOODLET, BRIAN LAIDLAW, Research Engineer, Metropolitan-Vickers Electrical Co., Ltd., Manchester, Eng.
*HASENPFLUG, ROY, Waterloo, Ont., Canada.
HILL, HORACE FLEMING, Consulting Expert, Public Utilities & Industrial Corp., Alden Park Manor, Brookline, Mass.
HOFFMAN, EDWIN CLARENCE, Electrical Engineer, Precise Mfg. Corp., 254 Mill St., Rochester, N. Y.
HOPKINS, LEWIS CUTHBERT, Maintenance Engineer, Mansell-Hunt & Catty, Lipton Bldg., Hoboken; res., Jersey City Heights, N. J.
HUGHES, EDWARD, Head of College, Elec. Engg. Dept., Municipal Technical College, Brighton, Eng.
HULCHER, THOMAS T., Thomas T. Hulcher Machine Works, 5-9 S. 7th St., Richmond, Va.
IDRAU, CHARLES M., Electrical Inspector, Public Service Production Co., 86 Park Place, Newark, N. J.
ILCH, WALTER ADOLPH, Inspector, Murrie & Co., 45 E. 17th St., New York; res., Woodside, N. Y.
KING, JAMES MERTON, Meter Tester, Meter Lab., Pennsylvania-Ohio Pr. & Lt. Co., Boardman & Champion Sts., Youngstown, Ohio.
KIRK, WILLIAM WALLACE, California District Mgr., Delta Star Electric Co., 212 I. W. Hellman Bldg., Los Angeles, Calif.
KLAK, JOHN JAMES, Senior Land Appraiser, Interstate Commerce Commission, Bureau of Valuation, Land Sec., Washington, D. C.
KRUEGER, HERBERT G., Heating & Appliance Salesman, Commonwealth Edison Co., 2345 W. Chicago Ave., Chicago, Ill.
LA MARSH, WILLIAM H., Appraisal Engineer, New York Edison Co., 120 E. 15th St., New York; res., Brooklyn, N. Y.
LANE, FRANK BERNARD, Operator, Ford Motor Co., River Rouge Plant, Detroit, Mich.
LANG, J. OLIVER, In charge of Standardizing Laboratory, Meter Dept., The Dayton Power & Light Co., Dayton, Ohio.
LAPP, REID, Electrical Construction Work, The Edward Ford Plate Glass Co., Rossford, Ohio.
LINDSAY, GEORGE WILLIAM, International Student, Educational Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh; res., Wilkinsburg, Pa.
*LOEHR, JOHN EDGAR, Engineering Assistant, New York Edison Co., 555 Tremont Ave., New York, N. Y.
MARIE, GEORGE WILLIAM, Engineering Dept., Century Electric Co., St. Louis, Mo.
MARTIN, FRANK G., Engineer, W. L. Hutchison Electric Co., 306 East 14th St., Kansas City, Mo.
*MAUNDER, SYDNEY THEODORE, Electrical Engineer, General Electric Co., Pittsfield, Mass.
MOORE, JOHN ALBERT, Electrical Draftsman, Engg. Dept., New York Rapid Transit Commission, Brooklyn; res., New York, N. Y.
MUZZY, L., General Correspondent, Westinghouse Elec. & Mfg. Co., 2124 Wyandotte, Kansas City, Mo.
NEBLETT, WILLIAM ROBERT, Jr., Designing Engineer, Memphis Power & Light Co., Memphis, Tenn.
NEWELL, PAUL EDGAR, Engineer, Western Electric Co., Inc., 346 Claremont Ave., Jersey City, N. J.
NORMAN, NATHANIEL CRUSE, Research Engineer, Bell Telephone Laboratories, 463 West St., New York, N. Y.
*PARTRIDGE, KENNETH LATCHER, Electrical Engineer, Eng. Dept., Hartford Electric Lt. Co., 266 Pearl St., Hartford, Conn.
PHELPS, WILLIAM HOWARD, Commercial Manager, Omaha & Lincoln Railway & Light Co., Ralston, Nebr.
PINGEL, HUGO JOHN, Armature Winding, The Edward Ford Plate Glass Co., Rossford; res., Toledo, Ohio.
POTTER, BERTRAM MATHEW, Apprentice Tester, Bureau of Power & Light, City of Los Angeles, 207 So. Broadway, Los Angeles, Calif.
*RASTALL, JOHN WESLEY, Planning Engineer, Western Electric Co., Inc., 1505 Race St., Philadelphia, Pa.
RICHARDS, WILLIAM, Winder, Weirton Steel Co., Weirton, West Va.: res., Steubenville, Ohio.
RYAN, VICTOR ANTHONY, Technical Director, Irvington Varnish & Insulator Co., 10 Argyle Terrace, Irvington; res., Hilton, N. J.
SCHIRMER, WILLIAM OLIN, 129 Hancock St., Cambridge, Mass.
SCHWARTZ, CLAUDE ELSWORTH, Operator, Toronto Station, Ohio River Edison Co., Toronto, Ohio.
SERVATZY, ROBERT CARL, Electrical Draftsman, Commonwealth Edison Co., 72 W. Washington St., Chicago, Ill.
SHERBORNE, FREDERICK GRANTHAM, Electrical Superintendent, Pacific Mills, Ltd., Ocean Falls, B. C.
STUEDAHL, LEIF, Draftsman, Liberty Electric Co., Fairfield Ave., Stamford, Conn.
SUNDBY, JOHN, Laboratory Assistant, Brooklyn Edison Co., Inc., Pearl & Willoughby Sts., Brooklyn, N. Y.
SZABO, ALEXANDER, Jr., Foreman, Testing Laboratory, Public Service Corp. of N. J., Clinton Ave. & 21st St., Irvington; res., New Brunswick, N. J.
TAKEDA, SHOICHI, Asst. Engineer, Electrical Bureau, Government Railways of Japan, Marunouchi, Tokio, Japan.
TEN BROOK, JOHN ABRAM, Engineering Assistant, Dist. Dept., The Counties Gas & Electric Co., 212 De Kalb St., Norristown, Pa.
VOGELI, RUDOLF, Electrical Designer, Stone & Webster, 147 Milk St., Boston; res., Watertown, Mass.
von BRAND, E. KURT, Electrical Engineer, Priess Radio Corp., 693 Broadway, New York, N. Y.
WHIPPLE, R. G., Engineer, Operating Dept., Electric Storage Battery Co., 1058 S. Vandeventer Ave., St. Louis, Mo.
WINETSKY, MICHAEL CHARLES, Meter Man, Public Service Electric Co., 71 Murray St., Elizabeth; res., Linden, N. J.
YOUNG, DONALD D., Cable Tester, American Tel. & Tel. Co., 40 Rector St., New York, N. Y.
YOST, JOHN CHARLES, Engineer, Radio Corp. of America, Rocky Point, N. Y.

Total 76

*Formerly enrolled Students

ASSOCIATES REELECTED NOVEMBER 24, 1925

MOORE, HERBERT S., Salesman, Central Sta. Div., Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.
OSGYAMI, GASTON LOUIS, Transmission Dept., American Tel. & Tel. Co., 24 Walker St., New York, N. Y.

OSTERMAN, G. R., Field Representative, McGraw-Hill Co., 514 S. Westlake Ave., Los Angeles, Calif.
PICKARD, EDWARD E., Asst. Planning Engineer, American Engineering Co., Aramingo & Cumberland Sts., Philadelphia, Pa.
RAM SAMI, S. M., Works Manager, Sandal Oil Factory, Bangalore, India.
VAN RAALTE, ARNOLD B., Organization Engineer, U. S. Veterans Bureau, New York; res., Brooklyn, N. Y.

ASSOCIATE REINSTATED NOVEMBER 24, 1925

PAXSON, OLIVER H., Jr., Engg. Dept., The Philadelphia Electric Co., Philadelphia; for mail, Primos P. O., Delaware Co., Pa.

MEMBERS ELECTED NOVEMBER 24, 1925

BAIRD, ALBERT FOSTER, Prof. of Elec. Engg., University of New Brunswick, Fredericton, N. B.
CARY, CHARLES REED, Vice-President & Sales Manager, Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.
HERDMAN, WILLIAM JAMES, Telephone Engineer, Patent Counsel, Postal Telegraph-Cable Co., 253 Broadway, New York, N. Y.
MELLINGER, MEARLE C., Electrical Engineer, American Smelting & Refining Co., Rosita, Coahuila, Mexico; for mail, Auburn, N. Y.
MULLISON, JOHN HUGUS, General Superintendent, Hutchinson District, United Power & Light Corp., 117 N. Main St., Hutchinson, Kans.
STANTON, EDWARD J., Supt. of Electric Distribution, Laclede Gas Light Co., 11th & Olive Sts., St. Louis, Mo.
WAGNER, HERMAN A., Consulting Engineer, Mayer, Ariz.
WARREN, JAMES S., Manager, Central Sta. Div., Westinghouse Elec. & Mfg. Co., 717 S. 12th St., St. Louis, Mo.

RECOMMENDED FOR TRANSFER

The Board of Examiners, at its meeting held November 16, 1925, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the National Secretary.

To Grade of Fellow

COATES, WILLIAM A., Metropolitan Vickers Electrical Export Co., Tokyo, Japan.
COPLEY, ALMON W., Manager, Engineering Division, Westinghouse Electric & Mfg. Co., San Francisco, Calif.
HIBBARD, TRUMAN, Secretary and Chief Engineer, Electric Machinery Mfg. Co., Minneapolis, Minn.
LEEDS, MORRIS E., President, Leeds & Northrup Co., Philadelphia, Pa.
WENNER, FRANK, Physicist, Bureau of Standards, Washington, D. C.

To Grade of Member

BANNISTER, ALBERT, Chief Assistant, Switchgear Sales Dept., Metropolitan-Vickers Electrical Co., Ltd., Manchester, England.
EUSTIS, TRUMAN W., Superintendent, Canadian National Carbon Co., Ltd., Toronto, Ont.
FREEMAN, HADLEY F., Patent Lawyer, Cleveland, Ohio.
GILT, CARL M., Assistant Inside Plant Engineer, Brooklyn Edison Co., Brooklyn, N. Y.
GREEN, CHARLES W., Telephone Engineer, Bell Telephone Laboratories, Inc., New York.
HOFFMAN, WILLIAM L., Assistant Engineer, Puget Sound Power & Light Co., Seattle, Wash.
JENNINGS, PHILIP D., Assistant Engineer, Puget Sound Power & Light Co., Seattle, Wash.
LAMB, FRANK B., Consulting Engineer, Member of Firm, West Virginia Engineering Co., Charlestown, W. Va.
LOCKWOOD, ALVAH M., Field Superintendent, Phoenix Utility Co. of Cuba, Cienfuegos, Cuba.
LOWENBERG, MAURICE J., Electrical Engineer, Stone & Webster, Inc., Boston, Mass.
LOWRY, HITER H., Telephone Engineer, Bell Telephone Laboratories, Inc., New York.
MACIAS, Carlos, Chief Engineer, Electromotor, S. A., Mexico D. F., Mexico.
MUSSER, HARRY P., President, West Virginia Engineering Co., Charleston, W. Va.
NETTLETON, LEROY A., Engineering Assistant, Brooklyn Edison Co., Brooklyn, N. Y.
RAMIREZ, JAVIER P., Consulting Engineer-Professor, Escuela de Ingenieros Mecanicos Electricistas, Mexico City, Mexico.
REINMANN, F. L., Supt. Electric Department, Northern Indiana Gas & Electric Co., Hammond, Ind.
RHODES, WALTER K., Professor of Electrical Engineering, Bucknell University, Lewisburg, Pa.
SHEDD, HORACE E., Superintendent, Appalachian Power Co., Bluefield, W. Va.
STAHL, CHARLES J., Manager, Illuminating Engineering Bureau, Westinghouse Elec. & Mfg. Co., South Bend, Ind.
STEVENS, THEODORE, Consulting Engineer, London, England.
VALK, EUGENE E., Engineer, Los Angeles Office, General Electric Co., Los Angeles, Calif.
WALKER, EWART B., Electrical Engineer, Canadian National Railways, Toronto, Ont.
WHITE, EDWARD J., Secretary, Treasurer, Engineer, Harris Wright Co. Inc., Newark, N. J.
WILLIAMS, LeROY C., District Manager. Pacific Electric Mfg. Co., Los Angeles, Calif,

APPLICATIONS FOR ELECTION

Applications have been received by the Secretary from the following candidates for election to membership in the Institute. Unless otherwise indicated, the applicant has applied for admission as an Associate. If the applicant has applied for direct admission to a higher grade than Associate, the grade follows immediately after the name. Any member objecting to the election of any of these candidates should so inform the Secretary before December 31, 1925.

Alber, G. F., The Detroit Edison Co., Detroit, Mich.
Alexander, D. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Alifano, A., Brooklyn Polytechnic Institute, Brooklyn, N. Y.
Appleton, W. E., United Electric Lt. & Pr. Co., New York, N. Y.
Arche, M. P., Cubana Electricidad, Inc., Camaguey, Cuba
Arnold, G. W., Canadian Westinghouse Co., Ltd., Hamilton, Ont., Can.
Ashline, R., Dept. of Pub. Service, Bureau of Water Works & Supply, City of Los Angeles, Los Angeles, Calif.
Asplund, C. D., Consumers Power Co., Battle Creek, Mich.
Avery, A. B., Jr., University of Arkansas, Univ. Station, Fayetteville, Ark.
Ayres, E. D., Jackson & Moreland, Boston, Mass.
Ayres, F., The Southern Sierras Power Co., Riverside, Calif.
Babcock, G. M., Los Angeles Gas & Elec. Corp., Los Angeles, Calif.
Bailey, C. O., Radiologist, Dallas, Texas
Baker, A. J., Lakeside, Ont., Can.
Barker, J. W., (Member), Mass. Institute of Technology, Cambridge, Mass.
Baty, L. E., The Topeka Edison Co., Topeka, Kans.
Bauman, H. A., Bethlehem Steel Co., Bethlehem, Pa.
Baumgardner, C. G., Monongahela West Penn Public Service Co., Fairmont, W. Va.
Beart, E. A., Toronto Hydro-Electric System, Toronto, Ont., Can.
Beaumont, W. M., Bell Telephone Laboratories, Inc., New York, N. Y.
Becker, T., Commonwealth Edison Co., Chicago, Ill.
Beckerleg, H., Pacific Gas & Electric Co., San Francisco, Calif.
Bender, E., Goodyear Tire & Rubber Co., Akron, Ohio
Benson, O. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Bentley, E. F., G. & W. Specialty Co., Chicago, Ill.
Benyo, G., New York Edison Co., New York, N. Y.
Bergevin, W. P., Rensselaer Polytechnic Institute, Troy, N. Y.
Berry, C. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Berry, H. P., Chesapeake & Potomac Telephone Co., Washington, D. C.
Bevers, P. T., Electric Railway Improvement Co., Cleveland, Ohio
Blay, J. A., Canadian Westinghouse Co., Toronto, Ont., Can.
Bock, J. A., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Boman, C. E., (Member), Bell Telephone Laboratories, Inc., New York, N. Y. (Applicant for re-election.)
Boolba, P. M., Bell Telephone Laboratories, Inc., New York, N. Y.
Booth, L. F., Century Electric Co., St. Louis, Mo.
Bostwick, W. E., Wisconsin Public Service Corp., Green Bay, Wis.
Boswau, H. P., North Electric Co., Galion, Ohio
Boyau, J., French Thomson-Houston Co., International General Electric Co., Schenectady, N. Y.
Boyd, J. W. G., Jr., Canadian National Carbon Co., Toronto, Ont., Can.
Brackman, H., Jr., Union Electric Lt. & Pr. Co., St. Louis, Mo.
Brandt, W. A., Automatic Electric Co., Philadelphia, Pa.
Bridge, L. R., Cornell University, Ithaca, N. Y.
Brixner, F. W., General Railway Signal Co., Rochester, N. Y.
Brooke, H. L., Jr., Pacific Electric Mfg. Co., San Francisco, Calif.
Broughton, W. G., General Electric Co., Schenectady, N. Y.
Brown, N. E., Niagara, Lockport & Ontario Power Co., Buffalo, N. Y.
Brown, J. F., Elec. Dept., City of Longmont, Longmont, Colo.
Brown, R. L., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Browne, O. A., West Lynn Works, General Electric Co., West Lynn, Mass.
Brownlee, T., General Electric Co., Pittsfield, Mass.
Burrows, C. R., Bell Telephone Laboratories, Inc., New York, N. Y.
Burke, C. T., General Radio Co., Cambridge, Mass.
Button, C. T., Union Gas & Electric Co., Cincinnati, Ohio
Butzer, J. D., Westinghouse Elec. & Mfg. Co., Sharon, Pa.
Carmer, B. H., Jr., Rensselaer Polytechnic Institute, Troy, N. Y.
Carlson, P. E., Postal Telegraph-Cable Co., Chicago, Ill.
Carville, E. M., Westinghouse Elec. & Mfg. Co., Springfield, Mass.
Case, H. M., Western Union Telegraph Co., Detroit, Mich.
Cass, J. C., Jr., Music Master Corp., Philadelphia, Pa.
Catlin, F. H., General Electric Co., Erie, Pa.
Chambliss, J. M., Utica Gas & Electric Co., Utica, N. Y.

Chamberlain, H. L., Jr., Pennsylvania Power & Light Co., Hauto, Pa.
Chambliss, L. M., Dixie Construction Co., Birmingham, Ala.
Chapman, W., Missipi Power Co., Biloxi, Miss.
Chang, W., Westinghouse Elec. & Mfg. Co., Wilkinsburg, Pa.
Chann, T., Boston Radio Co., New York, N. Y.
Charest, J. G., East Penn Electric Co., Pottsville, Pa.
Chetham-Strode, A., General Electric Co., Schenectady, N. Y.
Chilofsky, J., Philadelphia Electric Co., Philadelphia, Pa.
Chopra, H. C., Westinghouse Elec. & Mfg. Co., Newark, N. J.
Cisin, H. G., 1400 Broadway, New York, N. Y.
Clark, W. B., General Electric Co., Denver, Colo.
Clarkson, A. J., (Member), New York Central Railroad, New York, N. Y.
Clayton, C. J., Canadian Westinghouse Co., Ltd., Hamilton, Ont., Can.
Clemence, E. I., Consulting Engineer, Jersey City, N. J.
Cobban, R. J., Westinghouse Elec. & Mfg. Co., Portland, Ore.
Cooper, J. B., General Electric Co., Schenectady, N. Y.
Corwin, J. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Cota, A. R., (Member), Business Publishers Int. Corp., New York, N. Y.
Cowan, C. S., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Craig, D. K., Weston Electrical Instrument Corp., Philadelphia, Pa.
Crane, R. E., Bell Telephone Laboratories, Inc., New York, N. Y.
Critsky, M., Freed-Eisemann Co., New York, N. Y.
Crone, R. H., Phoenix Utility Co., Hazleton, Pa.
Crosby, M. G., Radio Corp. of America, Belfast, Maine
Crosse, E. A., Standard Underground Cable Co., Perth Amboy, N. J.
Curl, H. C., Bell Tel. Laboratories, New York, N. Y.
Daus, G. A., The Detroit Edison Co., Detroit, Mich.
Davenport, J. C., Chesapeake & Potomac Tel. Co., Washington, D. C.
Davis, R. C., Bell Telephone Laboratories, Inc., New York, N. Y.
Delo, W. A., Pennsylvania & Ohio System, Youngstown, Ohio
Del Duke, V. J., Utah Copper Co., Magna, Utah
Denault, C. L., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Denmead, H., Appalachian Power Co., Bluefield, W. Va.
Dexter, H. W., Jr., H. C. Fugate Eng. Co., West Palm Beach, Fla.
Dhar, M., Frick Co., Waynesboro, Pa.
Dodge, W. L., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Donaldson, K. M., Electric Bond & Share Co., New York, N. Y.
Donovan, W. E., Consumers Power Co., Jackson, Mich.
Doty, W. E., Brunswick-Balke-Collender Co., Omaha, Nebr.
Dow, L. J., New York Telephone Co., Albany, N. Y.
Draper, T., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Drodjin, A. J., Stanford University, Stanford University, Calif.
Dunlop, J. J., New York Telephone Co., New York, N. Y.
Durant, W. T., Steam-Elec. Operating Engineer, City of Regina, Saskatchewan, Can.
Earle, J. W., General Electric Co., Newark, N. J.
Easley, R. M., General Electric Co., Schenectady, N. Y.
Eastman, A. V., University of Washington, Seattle, Wash.
Eldridge, T. I., Jr., Electric Service Supplies Co., Philadelphia, Pa.
Engstrand, W. A., Edison Elec. Ill. Co. of Boston, Boston, Mass.
Epletveit, H. H., United Elec. Lt. & Pr. Co., New York, N. Y.
Eubcler, F. L., Murrie & Co., New York, N. Y.
Faley, G. J. V., Bell Telephone Laboratories, Inc., New York, N. Y.
Farkas, S., Holophane Glass Co., New York, N. Y.
Farman, C. D., Murrie & Co., New York, N. Y.
Farmer, E. W., Canadian Marconi Co., Montreal, Que., Can.
Farrar, W. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Fearn, E. E., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Feaster, W. C., The Potomac Edison Co., Hagerstown, Md.
Fenlon, D. R. J., 73 W. 102nd St., New York, N. Y.
Filer, W. L., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Fischer, H. B., Bell Telephone Laboratories, Inc. New York, N. Y.
Fisher, G. H. B., Canadian & General Finance Co., Ltd., Toronto, Ont., Can.
Fithian, L. S., West Jersey Electrical & Construction Co., Camden, N. J.
Fitzgerald, J. W., The Van Blarcom Construction Co., Cleveland, Ohio
Ford, R. B., Memphis Power & Light Co., Memphis, Tenn.
France, W. H., Michigan Bell Telephone Co., Saginaw, Mich.
Freeman, M. T., East Technical High School, Cleveland, Ohio
Freshwaters, E. C., Fairbanks-Morse Co., South Haven, Mich.
Fuller, J. B., Philadelphia Electric Co., Philadelphia, Pa.
Furber, J. R., Northern States Power Co., Minneapolis, Minn.
Garin, A. N., General Electric Co., Pittsfield, Mass.
Gaubert, J. Q., N. Y. C. Board of Education. Vocational School for Boys, New York, N. Y.
Gialias, G. E., New York Edison Co., Brooklyn, N. Y.
Giering, P. L., Hudson Valley Coke Products Corp., Troy, N. Y.
Glenn, K. B., Central Florida Power & Light Co., Brooksville, Fla.
Goodwin, A. M., General Electric Co., Boston, Mass.
Goodwin, R. C., Westinghouse Elec. & Mfg. Co., Wilkinsburg, Pa.
Grantham, F. W., Jr., Brooklyn Edison Co., Brooklyn, N. Y.
Green, A., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Greene, F. M., Westinghouse Elec. & Mfg. Co., New York, N. Y.
Hamburger, F., Jr., Johns Hopkins University, Homewood, Baltimore, Md.
Hanna, W. M., General Electric Co., Schenectady, N. Y.
Hansen, B. H., H. L. Doherty & Co., New York, N. Y.
Hansen, E. B., The Pacific Tel. & Tel. Co., San Francisco, Calif.
Hardy, Helen W., Public Service Electric & Gas Co., Newark, N. J.
Harper, R. W., Bell Telephone Laboratories, Inc., New York, N. Y.
Heath, C. E., General Electric Co., Atlanta, Ga.
Henderson, F. L., General Electric Co., West Philadelphia, Pa.
Hesselmeyer, C. T., General Electric Co., Schenectady, N. Y.
Hill, B. R., Westinghouse Elec. & Mfg. Co., Chicago, Ill.
Hilyard, S. L., (Member), Illinois Pr. & Lt. Corp., St. Louis, Mo.
Hinkle, A. H., Chas. M. Dodson Coal Co., Beaver Brook, Pa.
Hoard, J. L., Ralston Industrial School, Pittsburgh, Pa.
Hoedemaker, P., 1066 McBride Ave., Little Falls, N. J.
Holladay, W. L., General Electric Co., Dallas, Texas
Holroyd, H. B., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Hood, K., Jr., Columbia Power Co., Cincinnati, Ohio
Horgan, J. G., (Member), Ohio Public Service Co., Cleveland, Ohio
(Applicant for re-election.)
Horr, R. L., (Member), Mountain States Tel. & Tel. Co., Denver, Colo.
Hotchkiss, T. M., General Electric Co., River Works, Lynn, Mass.
Howitt, N., Harvard Engineering School, Cambridge, Mass.
Hughes, L. L., International General Electric Co., Schenectady, N. Y.
Huntley, H. L., Wilkes-Barre Lace Mfg. Co., Wilkes-Barre, Pa.
Ide, C., Allis-Chalmers Mfg. Co., Milwaukee, Wis.
Irish, J., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Irwin, B., United Electric Light & Power Co., New York, N. Y.
Jackson, G. J., Brooklyn Edison Co., Brooklyn, N. Y.
Jackson, J. E., Lynchburg Traction & Light Co., Lynchburg, Va.
Jacobs, A. H., Alabama Power Co., Birmingham, Ala.
Jacoby, A. C., Pennsylvania Power & Light Co., Allentown, Pa.
Jenks, L. M., Westinghouse Elec. & Mfg. Co., Milwaukee, Wis.
Jenstead, S. E., N. Pacific Public Service Co., Bremerton, Wash.
Johnson, G., Commonwealth Edison Co., Chicago, Ill.
Johnson, M. S., Cumberland Tel. & Tel. Co., Jackson, Miss.
Johnson, R. C., Bell Telephone Laboratories, Inc., New York, N. Y.
Johnson, W. C., Ohio Bell Telephone Co., Springfield, Ohio
Johnson, W. T., Blau's Electric Shop, Middletown, Conn.
Johnston, O. D., D. M. Fraser, Ltd., Toronto, Ont., Can.
Joho, E. C., Bell Telephone Laboratories, Inc., New York, N. Y.
(Applicant for re-election.)
Joly, P. F., Brooklyn Edison Co., Brooklyn, N. Y.
Jones, L. S., Socony Burner Corp., Brooklyn, N. Y.
Jore, B., Brooklyn-Manhattan Transit Corp., Brooklyn, N. Y.
Kayser, C. F., Commonwealth Edison Co., Chicago, Ill.
Keller, C. W., General Electric Co., Denver, Colo.
Kelly, M. (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Kelly, M. J., Electric Service Corp., Shawinigan Falls, P. Q., Can.
Kelton, E. C., (Member), Corps of Engineers, U. S. Army, Washington, D. C.
Kemp, C. G. R., (Member), Electrical Engineer, Reading, Pa.
(Applicant for re-election.)
Kenneally, D. J., The New York Edison Co., New York, N. Y.
Kennedy, A. J., Bisbee, Arizona
Kent, P. N., Draftsman, City Engineer's Office, Kansas City, Mo.
Keppicus, H., Bell Telephone Laboratories, Inc., New York, N. Y.
King, D. C., Electrical World, McGraw-Hill Co., New York, N. Y.
Kingdon, H. F., Canadian Crocker-Wheeler Co. St. Catharines, Ont., Can.
Knopp, O. R. H., Submarine Signal Corp., Boston 9, Mass.

Koch, C. J., General Electric Co., Schenectady, N. Y.
Konn, F., General Electric Co., Schenectady, N. Y.
Kramer, W. B., Duquesne Light Co., Pittsburgh, Pa.
Kreider, R. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Kriegshausser, J., John S. Hart Continuation School, Philadelphia, Pa.
Kron, J., 69 West 52nd St., New York, N. Y.
Krueger, D. E., Western Union Telegraph Co. Philadelphia, Pa.
Kubale, J. C., General Electric Co., Schenectady, N. Y.
Kurtz, H. J., Commonwealth Power Corp., Jackson, Mich.
Kuttich, J., Electrical Engineer, 463 Manhattan Ave., New York, N. Y.
Lamborn, R., General Electric Co., Erie, Pa.
Lander, H. M., New England Tel. & Tel. Co., Boston, Mass.
Lasher, G. W., New York Telephone Co., New York, N. Y.
Lathrop, G. M., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Lauritzen, C. W., University of Arkansas, Fayetteville, Ark.
Lawson, C. B., Pennsylvania Power & Light Co., Shenandoah, Pa.
Lee, D. W., Inspector of Elec. Constr., Dept. of City Transit, Philadelphia, Pa.
Lee, E. M., Potomac Electric Power Co., Washington, D. C.
Lehrhaupt, B., Electrical Estimator, 3968 3rd Ave., Bronx, New York, N. Y.
Lemly, F. W., Philadelphia Electric Co., Philadelphia, Pa.
LeStourgeon, A. L., Bell Telephone Laboratories, Inc., New York, N. Y.
Liebert, H. H., Alabama Power Co., Birmingham, Ala.
Liebrecht, E. F., Chesapeake & Potomac Tel. Co., Washington, D. C.
Lightband, D. A., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Lindvall, F. C., California Institute of Technology, Pasadena, Calif.
Lodas, F. J., Electric Bond & Share Co., New York, N. Y.
Logan, C. R., Murrie & Co., Inc., New York, N.Y.
Lucas, M. J., General Electrical Co., Erie, Pa.
Lund, A. E., c/o Danish Consulate, 16 Bridge St., New York, N. Y.
Lyons, G. W., City of Chicago, Chicago, Ill.
MacGillivray, A. L., Western Electric Co., Inc., New York, N. Y.
Macgillivray, M. S., University of Toronto, Toronto, Ont., Can.
Macmillan, J., Interborough Rapid Transit Co., New York, N. Y.
Mahley, F. W., Westinghouse Elec. & Mfg. Co., Wilkinsburg, Pa.
Manigault, E. L., General Electric Co., Fairmont, W. Va.
Maretzo, C. B., Brooklyn Edison Co., Brooklyn, N. Y.
Mason, H. F., Llewellyn Iron Works, Los Angeles, Calif.
Mason, R. C., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Matthies, W. H., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Mays, P. E., Virginia-Western Power Co., Clifton Forge, Va.
McClain, W. J., Philadelphia Electric Co., Philadelphia, Pa.
McCluskey, F. J., Utah Power Co., Park City, Utah.
McCullough, M. B., General Electric Co., Schenectady, N. Y.
McCurdy, B. H., New England Tel. & Tel. Co., Boston, Mass.
McElheny, G. B., Duquesne Light Co., Pittsburgh, Pa.
McGee, J. S., (Member), Monongahela West Penn. Public Service Co., Grafton, W. Va.
McMurran, M. J., Grace Pr. Plant, Utah Power & Light Co., Grace, Idaho
Meaker, O. P., National Lamp Works, General Electric Co., Nela Park, Cleveland, Ohio
Mears, G. E., Michigan Bell Telephone Co., Detroit, Mich.
Meissner, E. R., General Electric Co., Schenectady, N. Y.
Merigan, E. L., General Electric Co., Schenectady, N. Y.
Merrill, L. H., Chas. H. Tenney & Co., Boston, Mass.
Meyer, F. T., Bell Telephone Laboratories, Inc., New York, N. Y.
Miller, A. T., International Paper Co., Glens Falls, N. Y.
Miller, R. J., Bell Telephone Laboratories, Inc., New York, N. Y.
Milligan, R. J., The Philadelphia Electric Co., Philadelphia, Pa.
Mills, G. H., Case School of Applied Science, Cleveland, Ohio
Mills, N., Century Electric Co., St. Louis, Mo.
Monseth, I. T., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Moore, C. H., Duquesne Light Co., Pittsburgh, Pa.
Moore, L. G., Jr., Florida Electric Supply Co., Miami, Fla.
Mortimer, L. A., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Moschel, W. K., Commonwealth Edison Co., Chicago, Ill.
Muckenhaupt, C. F., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Mueller, R., G. & W. Electric Specialty Co., Chicago, Ill.
Mueller, W. E., Syracuse University, Syracuse, N. Y.
Murphy, E. J., New York Telephone Co., Newark, N. J.
Murphy, F. A., Alfred Collyer & Co., Toronto, Ont., Can.
Murphy, P. B., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Myers, D. S., Bell Telephone Laboratories, Inc., New York, N. Y.
Nelson, W. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Niven, C. K., Atlantic Basin Iron Works, Brooklyn, N. Y.
Noble, R. E., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Noble, W. D., Bell Telephone Laboratories, Inc., New York, N. Y.
Novy, A. J., Wappler Electric Co., Inc., Long Island City, N. Y.
Oberndorf, E. S., (Member), The J. G. White Engg. Corp., New York, N. Y. (Application for re-election.)
Offerdahl, E., New York Central Railroad Co., New York, N. Y.
Oliver, R. S., Jr., Florida Electric Supply Co., Miami, Fla.
Owen, F. C., Inventor & Mfr. of Elec. Welding Apparatus, Fayetteville, N. C.
Palmer, G. H., Commissioned Officer, Signal Corps, U. S. A., Washington, D. C.
Parker, J., Jr., Philadelphia Electric Co., Philadelphia, Pa.
Parker, R. H., Pacific Tel. & Tel. Co., San Francisco, Calif.
Paul, H. J., Century Electric Co., St. Louis, Mo.
Paul, T., Bell Telephone Laboratories, Inc., New York, N. Y.
Penney, G. W., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Penney, W. M., Jr., Union Electric Lt. & Pr. Co., St. Louis, Mo.
Peterson, E., (Member), Western Electric Co., New York, N. Y.
Phillips, S. N., Century Electric Co., St. Louis, Mo.
Pilkington, J. H., Brooklyn Edison Co., Brooklyn, N. Y.
Preisman A., The New York Edison Co., Bronx, New York, N. Y.
Rae, O. O., Westinghouse Elec. & Mfg. Co., Atlanta, Ga.
Ranson, R. R., Cutler-Hammer Mfg. Co., Milwaukee, Wis.
Rapp, C. P., Bell Telephone Co. of Pennsylvania, Philadelphia, Pa.
Reardon, M. F., Mountain States Tel. & Tel. Co., Denver, Colo.
Reed, C. F., International Standard Electric Corp., New York, N. Y.
Reed, F. F., Public Service Elec. & Gas Co., Irvington, N. J.
Reed, G. V., Provincial Hospital, Prov. of Saskatchewan, Can.
Reed, H. R., Jr., Norfolk & Western Railway Co., Roanoke, Va.
Reed, W. H., Tietjen & Lang Dry Dock Co., Hoboken, N. J.
Richard, E. C., Florida Power & Light Co., Miami Beach, Fla.
Richardson, M. S., Wisconsin Telephone Co., Milwaukee, Wis.
Rihanek, L. F., T. E. Murray, Inc., New York, N. Y.
Ripley, N. A., Phoenix Utility Co., Cienfuegos, Cuba.
Roberts, G. A., Bell Telephone Laboratories, Inc., New York, N. Y.
Robertson, G. B. M., Philadelphia Electric Co., Philadelphia, Pa.
Robson, J. G., British Columbia Elec. Railway Co., Vancouver, B. C.
Roeser, J. P., Brooklyn Edison Co., Inc., Brooklyn, N. Y.
Rohde, C. F., Murrie & Co., New York, N. Y.
Rollow, J. G., Los Angeles Gas & Electric Corp., Los Angeles, Calif.
Rolnick, H., International Motor Co., New Brunswick, N. J.
Rosenburg, E. R., Cornell University, Ithaca, N. Y.
Ross, D., Bell Telephone Laboratories, Inc., New York, N. Y.
Roth, J. E., Western Union Telegraph Co., Kansas City, Mo.
Rowland, D. H., Locke Insulator Corp., Baltimore, Md.
Rumsey, P. T., Mass. Institute of Technology, Cambridge, Mass.
Sams, J. H., Jr., Cornell University, Ithaca, N. Y.
Sapper, R. T., Century Electric Co., St. Louis, Mo.
Schacht, D. H., Century Electric Co., Rochester, N. Y.
Schardt, F. O., Public Service Production Co., Kearny, N. J.
Schlechter, A. H., N. Y. & Q. Elec. Lt. & Pr. Co., Flushing, N. Y.
Schmidt, E., N. Y., & Queens Elec. Lt. & Pr. Co., Flushing, N. Y.
Schnitter, R. M., Western Electric Co., Inc., Chicago, Ill.
Schroeder, J. H., Commonwealth Edison Co., Chicago, Ill.
Shea, D. C., Standard Oil Co., Bayway Refinery, Elizabeth, N. J.
Shelley, H. S., Consolidated Gas & Electric Co., Baltimore, Md.
Shope, H. S., (Member), Bell Telephone Laboratories, Inc., New York, N. Y.
Simon, R. B., Bell Telephone Laboratories, Inc., New York, N. Y.
Sipkin, G., Interborough Rapid Transit Co., New York, N. Y.
Siskind, C. S., Milwaukee Vocational School, Milwaukee, Wis.
Skene, A. A., Union Switch & Signal Co., Swissvale, Pa.
Skinner, W. A., Pennsylvania Power & Light Co., Hazleton, Pa.
Smith, A. C., Freed-Eisemann Radio Corp., Brooklyn, N. Y.
Smith, A. W., Murrie & Co., New York, N. Y.
Smith, E. R., Bell Telephone Laboratories, Inc., New York, N. Y.
Smith, G. K., (Member) Bell Telephone Laboratories, Inc., New York, N. Y.

Smith, H. M., S. Edw. Eaton & Co., New York, N. Y.
Sonnemann, W. K., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
Stanka, E. W., H. L. Doherty & Co., New York, N. Y.
Stanley, J. S., Los Angeles Railway Corp., Los Angeles, Calif.
Sternberg, T. A., New York Rapid Transit Co., Brooklyn, N. Y.
Stroessler, H. M., Commonwealth Edison Co., Chicago, Ill.
Strong, E. M. Cornell University, Ithaca, N. Y.
Stumpf, M. W., New Orleans Public Service, Inc., New Orleans, La.
Sutherland, G. E., Gibbs & Hill, Mullins, W. Va.
Swan, W. D., Interborough Rapid Transit Co., New York, N. Y.
(Applicant for re-election.)
Swords, E. L., California-Portland CementCo., Colton, Calif.
Tanck, H., General Electric Co., River Works, West Lynn, Mass.
Taylor, A. L., New York Telephone Co., Albany, N. Y.
Taylor, J. R., Westinghouse Elec. & Mfg. Co., Wilkes-Barre, Pa.
Taylor, W. P., Cons. Gas Electric Lt. & Pr. Co., Baltimore, Md.
Teall, H. A., Kansas State Agricultural College, Manhattan, Kans.
Therrien, R. W., Commonwealth Power Corp., Jackson, Mich.
Thielemann, G. J., Public Service Co. of No. Illinois, Blue Island, Ill.
Thompson, S. W., Dayton Co-operative High School, Dayton, Ohio
(Applicant for re-election.)
Thomson, J. M., Canadian Crocker-Wheeler Co., St. Catharines, Ont., Can.
Townsend, R. L., Chesapeake & Potomac Telephone Co., Washington, D. C.
Travers, F. H., New England Tel. & Tel. Co., Boston, Mass.
Treptow, F. W., Bell Telephone Laboratories, Inc. New York, N. Y.
Turner, C. P., (Member), General Electric Co., Schenectady, N. Y.
(Applicant for re-election.)
Upham, E. H., French Cable Co., Orleans, Mass.
Van Denburg, E. D., The Montana Power Co., Great Falls, Mont.
Vassallo, A., General Electric Co., New York, N. Y.
Voorhies, M. B., (Member), Louisiana State University, Baton Rouge, La.
Vroom, E., Bell Telephone Laboratories, Inc., New York, N. Y.
Waits, C. E., Utica Gas & Electric Co., Utica, N. Y.
Wall, C. L., Jr., General Electric Co., West Lynn, Mass.
Walter, G. D., Auto. Electrical Business, Biglerville, Pa.
Walworth, S. L., (Member), Pittsburgh Transformer Co., Pittsburgh, Pa.
Watson, D. R., Philadelphia Electric Co., Philadelphia, Pa.
Weaver, E. F., Pennsylvania Power & Light Co., Mt. Carmel, Pa.
Werner, H. D., General Electric Co., Erie, Pa.
Wetherell, D. H., Bell Telephone Laboratories, Inc., New York, N. Y.
Williams, H. K., Hartford Electric Light Co., Hartford, Conn.
Williams, T., East Penn Electric Co., Minersville, Pa.
Wilson, M. S., Standardizing Lab., General Electric Co., West Lynn, Mass.
Winslow, J. C., Westinghouse Elec. & Mfg. Co., East Springfield, Mass.
Wishart, R. S., (Member), Postal Telegraph-Cable Co., New York, N. Y.
Witbeck, A. L., Chicago, Milwaukee & St. Paul Railway Co., Chicago, Ill.
Wolf, H. B., Southern Power Co., Salisbury, N. C.
Wolfe, T. M., Westinghouse Elec. & Mfg. Co., Wilkes-Barre, Pa.
Wright, R. M., Cincinnati Street Railway Co., Cincinnati, Ohio
Wynkoop, F. B., Interborough Rapid Transit Co., New York, N. Y.

Total 379

Foreign

Bhusari, V. G., V. J. Technical Institute, Matunga, Bombay, India
Cramp, W., (Member), University of Birmingham, Edgvaston, Birmingham, Eng.
Dann, T. W., General Electric Co., Witton, Birmingham, Eng.
Duboe, C. H., Elec. Pr. Plant's Inspector, Ministerio Obras Publ. Prov. Buenos Aires, S. A.
Eder, H. H., Cali Electric Light & Power Co., Cali, Rep. of Colombia, S. America
Fabinger, F., Ceskomoravska-Kolben a. s., Prague, Vysocany, Czechoslovakia
Jones, A. T., New S. Wales Railway Commissioners, Newcastle, New South Wales, Aus.
Kindberg, E., Electricity Dept., Borough Council, New Plymouth, N. Z.
Lemaire, A. E. Water Conservation & Irrigation Comm., Leeton, N. S. W., Aust.
Lewis, W. K., Messrs Ferguson Pailin, Ltd., London, W. C. 2, Eng.
Oake, C. J., British Municipal Council, Tientsin, N. China
Powell, J. H., with R. E. Berry, Christchurch, N. Z.
Safdar, H., G. I. P. Railway, Matunga, Bombay, India
Setna, J. A., Doslani Bldg., Bombay, India
Smith, H. R., (Member), School of Mines & Industry, Bendigo, Victoria, Australia
Tallianos, P. C., Greek Academy, Alexandria, Egypt
Wolf, R., Jr., Bahnhofstr 19, Mittweida, Sa., German

Total 17

STUDENTS ENROLLED NOVEMBER 16, 1925

Aaker, Oscar A., University of North Dakota
Aakhus, T. T., University of Colorado
Abakumoff, K. V., University of Washington
Adriansen, John R., Marquette University
Agruda, Mariano M., University of Michigan
Albert, Charles E., University of Kentucky
Albert, G. A., Pennsylvania State College
Albert, J. Guy, Marquette University
Allen, Carey S., South Dakota State School of Mines
Allen, S. Russell, State College of Washington
Allison, J. G., McGill University
Anderson, Frank G., Lehigh University
Anderson, Lloyd, University of Washington
Anderson, Nels A., University of North Dakota
Armstrong, George C., University of Illinois
Augustadt, Herbert W., University of N. Dakota
Augustine, Winfield J., Clarkson College of Technology
Austin, Joseph W., University of Kentucky
Avalos Vez, Leon, Escuela de Ingenieros Mecanicos y Electricistas
Ayers, Paul, Kansas State Agricultural College
Babbitt, Harry, Kansas State Agricultural College
Bailey, Lester W., Oregon State Agricultural College
Baker, S. V., University of Kentucky
Balla, Julius A., University of Pittsburgh
Barbor, Verner H., Pennsylvania State College
Barrett, J. F., University of Oklahoma
Basehore, Emmert H., Pennsylvania State College
Bates, Robert P., Drexel Institute
Baudino, J. E., University of Illinois
Baugh, Earl H., Washington State College
Baum, Thomas E., University of Pittsburgh
Beardsley, Charles H., University of Michigan
Beattie, Walter D., Washington State College
Beggs, George H., Lehigh University
Beggs, Thomas P., University of Illinois
Bell, Charles W., University of Kentucky
Bemis, Oliver B., Clarkson College of Technology
Benetier, Leon, State University of Iowa
Benham, Cecil L., University of Colorado
Bentley, James O., South Dakota State School of Mines
Berry, Glenn H., University of California
Biddulph, Harold J., Iowa State College
Bidwell, Charles H., California Institute of Technology
Binns, C. B., West Virginia University
Bjorquist, Carl H., Ore. Agricultural College
Blanchett, Luther, Washington State College
Blankenburg, R. Carter, California Institute of Technology
Bobe, Stanley A., Washington State College
Boegler, Stanley, University of South Dakota
Boehme, Herbert H., Washington State College
Boeke, Arthur C., State University of Iowa
Bohlke, W. Hollander, Rutgers University
Brady, Charles I., Jr., Lehigh University
Brady, George B., University of Oklahoma
Bredehoft, Harold A., Kansas State Agricultural College
Brekke, Theodore N., University of South Dakota
Briggs, Richard S., University of California
Britton, Challis, Lehigh University
Bronaugh, Joseph, University of Virginia
Brosens, Rene, Mass. Institute of Technology
Brown, Paul M., University of Colorado
Brownell, George R., Syracuse, N. Y.
Brush, Lucien M., University of Pittsburgh
Buchholz, William F., University of Wyoming
Bue, Norman, University of North Dakota
Burchfield, Clinton R., Pennsylvania State College
Burley, Franklin A., Clemson College
Burnett, Oliver F., Jr., University of Illinois
Busse, Leonard F., Syracuse University
Byrd, William, Jr., Harvard University
Campbell, Leroy, Purdue University
Cardwell, Fox, Jr., Alabama Polytechnic Institute
Carney, Lester G., Clarkson College of Technology
Carothers, William D., University of Pittsburgh
Carpenter, Burton C., Syracuse University
Carr, James M., Lehigh University
Carrie, John, Northwestern University
Caruthers, Robert S., University of Maryland
Castor, Earl H., Ore. Agricultural College
Cecil, J. Bernard, Iowa State College
Chase, Harry J., University of Michigan
Chiodo, Leo J., Lehigh University
Clark, Clark H., University of Colorado
Clark, Edwin A., Drexel Institute
Clark, Nathan C., University of California
Clayman, Bernard, Northeastern University
Cofer, Thomas N., Purdue University
Coffman, Charles M., University of Colorado
Coker, George T., University of Pittsburgh
Collins, Wilbert G., University of California
Compton, F. M., University of Washington
Coombe, Charles N., Syracuse University
Cornell, Glenn H., West Virginia University
Corrao, Joseph, University of California
Cortelyou, W. Harlan, Rutgers University
Craig, Robert B., South Dakota State School of Mines
Cramer, Harold, University of Pittsburgh
Crosby, Howard M., University of South Dakota
Crose, Harold G., University of Utah
Cross, Norman W., University of North Dakota
Crowther, F. D., Ore. Agricultural College
Culbertson, George A., University of Pittsburgh
Curran, Clifford L., South Dakota State School of Mines
Curtis, Lowell, Ore. Agricultural College
Dallas, Maurice H., Alabama Polytechnic Institute
Dallavalle, Joseph M., Harvard University
Dalziel, Charles F., University of California
Dancy, J. L., Lehigh University
Danielson, Willard G., University of South Dakota
Darnell, Thomas H., Mass. Inst. of Technology
Dart, David M., University of California
Davis, Dallas R., University of Oklahoma
Davis, J. A., Clemson Agricultural College
Davis, Willis F., West Virginia University

Dayhoff, Francis J., South Dakota State School of Mines
Dean, Francis P., University of Florida
De Lay, George R., Georgia School of Technology
Demeter, Julius, Rutgers University
Demmer, A. Harold, University of Illinois
Deutsch, Kenneth T., University of Colorado
Devine, Perle A., Iowa State College
Dier, Irving L., South Dakota State School of Mines
Dimond, T. Leone, State University of Iowa
Dixon, Elmer D., University of Oklahoma
Doohen, Will, University of South Dakota
Doty, Paul I., University of California
Doub, Donald V., University of California
Douglas, Louis R., University of Illinois
Dugger, Ralph L., University of Illinois
Dunstan, Arthur M., Alabama Polytechnic Institute
Durgin, Carey L., University of Washington
Durham, Herbert I., Kansas State Agricultural College
Eade, Harold J., South Dakota State School of Mines
Early, Fred J., University of California
Edelstein, William, University of Florida
Edwards, Paul M., Georgia School of Technology
Eichhorn, Carol E., University of Illinois
Eielson, Arthur B., University of North Dakota
Eininger, Robert S., Jr., Drexel Institute
Eisenbrown, Paul D., Lehigh University
Eldridge, Raymond E., Northeastern University
Elliott, Earl R., Purdue University
Ellis, Owen W., University of Utah
Elwell, Maynard, Northeastern University
Espenschade, Park W., Drexel Institute
Evjen, Haakon M., Cornell University
Ewing, Samuel C., University of Kentucky
Falkovich, O. C., University of Washington
Faust, A. E., Rose Polytechnic Institute
Fereshetian, Vahan H., University of California
Ficke, James H., Iowa State College
Fishburne, Francis J., Clemson College
Fisher, Lyle C., Purdue University
Fitzgerald, Edward R., Syracuse University
Florence, Virgil D., University of Kentucky
Folgelsanger, Aldus, Bucknell University
Folgelsonger, G. Leonard, Bucknell University
Formoso, Jose, Escuela de Ingenieros Mecanicos y Electricistas
Fossati, Nicholas, Jr., University of California
Fox, Francis K., University of California
Fox, James J., State University of Iowa
Frank, William M., Alabama Polytechnic Institute
Fryer, James J., South Dakota State College
Gaston, L. D., Clemson Agricultural College
Geist, Charles P., Bucknell University
Gibb, John V., Lehigh University
Giese, T. F., University of North Dakota
Giovanini, Frank, University of Washington
Gowin, Wilks W., University of Colorado
Graff, Joseph W., University of Florida
Graydon, Stafford W., Georgia School of Technology
Grewal, Balwant S., University of Utah
Gubser, Regis S., California Inst. of Technology
Guernsey, Elwood D., University of Michigan
Haas, Charles F., Lehigh University
Halberg, Maynard N., University of California
Harms, Gordon J., University of Kansas
Harrington, Hugh E., University of Oklahoma
Hartman, E. T., West Virginia University
Hartman, Frank C., University of Pittsburgh
Hauser, Willard G., Pennsylvania State College
Hawk, Thore C., University of N. Dakota
Hayes, Robert D., Iowa State College
Heine, L. Joseph, Lehigh University
Heiney, Charles H., Purdue University
Heinrich, Herbert, Lafayette College
Hendee, Malcolm H., Jr., Clemson College
Henderson, Claude E., University of Oklahoma
Henderson, William T., University of Illinois
Hensel, Marion L., University of Colorado
Hettel, Earl F., University of Illinois
Hickman, Gordon K., Iowa State College
Higgins, Robert E., University of California
Hill, A. M., Rhode Island State College
Hirsh, Daniel, Purdue University
Hodge, Arthur O. A., University of California
Hodgkins, Whitney C., University of California
Hoffman, Charles E., University of Utah
Hogan, Mervin B., University of Utah
Hollingsworth, Frank H., Purdue University
Holtzclaw, John P., Jr., University of Kentucky
Hopkins, Henry, Rhode Island State College
Horn, Chris A., Washington State College
Hossack, Hugh A., California Inst. of Technology
Houghton, Henry G., Drexel Institute
Howard, Alan, Purdue University
Hoyer, Henry E., University of South Dakota
Huffine, Charles W., University of Washington (Seattle)
Huhtala, Sylvester, University of Wyoming
Hunter, Eugene M., Worcester Polytechnic Inst.
Ingraham, William L., University of California
Jackel, Arthur P., Pennsylvania State College
Jackson, Lloyd R., University of Colorado
Jasper, Henry N., Jr., Harvard University
Jedlicka, Frank E., Lehigh University
Jenner, Melvin A., University of Washington
Jennerson, H. L., University of Washington
Jensen, George G., University of Washington
Johnson, Ervin G., University of California
Johnson, Frederick A., University of Washington
Johnson, J. Dick, Bucknell University
Johnson, Melvin E., University of Washington
Johnson, Roger L., University of Pittsburgh
Johnston, Elmer R., University of N. Dakota
Jones, James L., Alabama Polytechnic Institute
Kahn, Brighton A., Kansas State Agricultural College
Kahn, Louis, Rutgers University
Kaneko, G. S., California Institute of Technology
Karns, Melvin E., Kansas State Agricultural College
Kaufman, Abraham A., University of California
Kaufmann, Richard H., Iowa State College
Kearns, Earl E., Ore. Agricultural College
Kemp, Theodore, Lehigh University
Kent, Eugene F., Clarkson College of Technology
Kesheimer, Eugene V., University of Kentucky
Kesler, Reginald E., Washington & Lee University
King, Alfred R., University of California
King, M. Eugene, Jr., Pennsylvania State College
Kingsley, Charles, Jr., Mass. Inst. of Technology
Kirkland, Henry E., Ore. Agricultural College
Kirkland, Walter N., University of California
Kirkman, William L., Purdue University
Kistler, J. Fred, University of North Carolina
Knoll, William C., University of California
Krell, Ernest O., University of Illinois
Krieger, Alvin W., Marquette University
Kroger, B. J., Catholic University of America
LaBrush, William, Marquette University
Laird, James V., University of Utah
Lakas, John M., Cornell University
Lalley, Edward B., University of Kentucky
Landers, Elmo W., Ga. School of Technology
Lantz, Martin J., Ore. Agricultural College
Larkins, James F., Drexel Institute
Latham, George R., West Virginia University
Lathe, Warren S., Ga. School of Technology
Laurence, Warren H., Syracuse University
Lavigne, Hilaire J., Marquette University
Lefevre, George L., University of Virginia
Leidy, Lester W., Lehigh University
Lemmer, Vernon E., University of Wisconsin
Leonnig, Leo J., Ore. Agricultural College
Letsinger, Everett, Rose Polytechnic Institute
Lewis, Albert F., Ore. Agricultural College
Lindemer, Raymond M., Purdue University
Lindersmith, Paul M., Ohio Northern University
Livingston, Orrin W., Rutgers University
Long, Earnest R., West Virginia University
Loomis, George E., Lehigh University
Lowry, Lewis, University of Washington
Lundy, Clarence A., Ga. School of Technology
Lundy, R. Theodore, University of Florida
Lyle, William H., University of Florida
Lyon, Calvin S., Kansas State Agricultural College
Lyons, John McK., Cornell University
Maag, Ernst, California Institute of Technology
Maccono, John D., University of Illinois
MacGregor, Wallace R., Clarkson College of Technology
Machen, C. Raymond, University of California
Machorro, Ricardo, Escuela de Ingenieros Mecanicos y Electricistas
Maddox, William A., Jr., Georgia School of Technology
Magnus, Neal H., University of California
Maltby, Calvin S., Clarkson College of Technology
Mangan, George B., Catholic University of America
Manner, Richard J., Lehigh University
March, Laurel A., Kansas State Agricultural College
Martin, George M., University of Washington (Seattle)
Marx, Sylvester J., Marquette University
Masek, F. E., Kansas State Agricultural College
Mathews, John B., Ga. School of Technology
Mayes, Thorn L., University of California
McCrory, Aaron F., University of Illinois
McFarland, Russell, University of Arkansas
McGavock, Hugh K., Ga. School of Technology
McGlade, Arthur B., University of California
McGraw, Patrick R., Marquette University
McKeel, Percy D., South Dakota State School of Mines
McMillan, D. G., University of Florida
McTaggart, Francis E., University of Pittsburgh
Meahl, Harry R., Washington State College
Melang, Bjorn L., University of Washington
Merrill, Arthur A., University of California
Metcalf, C. N., Rensselaer Polytechnic Institute
Metz, John H., Lehigh University
Middleton, Edwin B., Drexel Institute
Miles, Marion L., Ga. School of Technology
Millar, A. Elkin, Cornell University
Miller, Arthur W., Purdue University
Miller, L. R., Clemson Agricultural College
Mills, Joseph F., Washington State College
Miyauchi, Masaru H., University of California
Moench, Theodore S., Rose Polytechnic Institute
Moore, Charles W., West Virginia University
Morris, Edward P., University of Kentucky
Morrison, R. E., University of Illinois
Moseman, C. G., University of Maryland
Mosley, Carl E., Iowa State College
Muller, Henry S., West Virginia University
Mullineaux, Frederic, Rutgers University
Neff, Elwood N., University of Colorado
Nelles, Maurice H., University of South Dakota
Nesbit, Donald G., University of Pittsburgh
Newcomb, Josiah T., Mass. Inst. of Technology
Newell, Clyde S., University of Colorado
Nicholas, Joseph A., Lehigh University
Nicholes, Farrell J., University of Utah
Nichols, Charles F., University of Michigan
Nichols, Elmer F., University of Arkansas
Nichols, Perry P., University of Vermont
Nicoles, Elton W., University of California
Nodder, William R., University of California
Norris, Gerald W., University of Illinois
Nourse, Charles F., University of California
Nyhart, Will D., Kansas State Agricultural College
O'Bar, Alfred S., University of Arkansas
O'Dwyer, John M., University of Colorado
Oliver, T. H., University of Kentucky
Olson, George C., University of California
Olson, Harry W., University of North Dakota
Olson, Lawrence B., South Dakota State School of Mines
O'Nan, John W., University of Kentucky
Page, W. M., Washington & Lee University
Parker, Robert C., Purdue University
Patterson, Harold D., Northeastern University
Pattillo, James G., Jr., University of Pittsburgh
Pawley, Myron G., Cornell University
Penther, Carl J., University of California
Perkins, Edwin L., Clarkson College of Technology
Peters, Kenneth O., Kansas State Agricultural College
Peterson, Alvin E., University of California
Peterson, Gilbert C., Iowa State College
Peterson, N. Trumond, Ore. Agricultural College
Pexton, Frank S., University of Colorado

Phelps, Houston S., Cornell University
Phillips, Arthur H., Lehigh University
Pickhaver, Lionel G., University of Michigan
Pierce, Ira E., Lehigh University
Pippenger, Edward E., Purdue University
Pitcher, Thomas A., Ore. Agricultural College
Plette, A. Lednum, University of Pittsburgh
Polk, Orval H., University of Colorado
Porter, Joseph H., South Dakota State School of Mines
Powell, Edward H., University of Pittsburgh
Powell, Harold C., Rutgers University
Presbrey, Walter A., Jr., Rhode Island State College
Primm, John F., University of Illinois
Pringle, William A., Iowa State College
Ranzenbach, Oscar, Ore. Agricultural College
Reddington, Edwin R., University of Kansas
Reddy, Ernest F., Ore. Agricultural College
Reed, Neil C., Syracuse University
Reise, Herman, University of Washington
Rice, George B., Ore. Agricultural College
Richards, Horace J., Drexel Institute
Richards, John S., State College of Washington
Richards, Wilbur O., University of Colorado
Richards, William T., Purdue University
Richardson, Jesse S., University of Wyoming
Riefle, James H., Jr., Lehigh University
Rights, Herbert T., Lehigh University
Risius, John C., State University of Iowa
Rocca, Bernard, University of California
Rogers, Edgar, Purdue University
Ross, Robert D., University of Florida
Roth, Herman M., University of Virginia
Rue, Albert, Rutgers University
Rupp, William B., Bucknell University
Rutherford, Elwin, Kansas State Agricultural College
Russell, Lee B., University of Kentucky
Sartain, Luther B., Jr., Catholic University of America
Sawyer, Clifford C., Kansas State Agricultural College
Schlosoberg, Victor E., Rose Polytechnic Institute
Schreiner, Louis R., Lehigh University
Schroeder, C. J., Washington State College
Schuknecht, Robert C., Ore. Agricultural College
Scott, Royal L., University of South Dakota
Scullin, Floyd B., University of California
Searle, George W., University of Colorado
Setter, Joe A., University of Colorado
Severin, Herman C., University of California
Seymour, Frank, University of Kansas
Shafer, Berkeley R., West Virginia University
Shelley, Perry L., University of California
Shiomi, Roy Y., University of Washington
Shipley, Herbert M., Lehigh University
Shuster, George M., University of Delaware
Siddons, Edwin C., Rutgers University
Silverman, Daniel, University of California
Simpson, Alfred J., Michigan State College
Smedley, Barr W., University of Utah
Smith, Bruce H., University of Florida
Smith, Edward F., University of Florida
Smith, Irvin L., West Virginia University
Smith, John R., University of Kentucky
Smith, Milo R., University of California
Smith, William V., University of California
Snider, Floyd, University of Washington
Sobota, Erich M., University of Illinois
Soucy, Chester I., University of Toronta
Spassky, Gleb A., California Inst. of Technology
Soule, Floyd M., George Washington University
Sparks, Robert, Lehigh University
Spatz, Norman S., Lehigh University
Spaulding, Arthur M., Purdue University
Spears, Ramon L., University of Kentucky
Spicer, Russell F., Clarkson College of Technology
Staller, Alfred W., Lehigh University
Stanley, C. Max, State University of Iowa
Stanwix-Hay, Walter H., University of Florida
Steele, C. Anson, Iowa State College
Stewart, Kermit D., West Virginia University
Stillman, T. H., Harvard Engineering School
Stoddard, Elwood, Lehigh University
Strizich, William E., University of California
Strock, Earl E., University of California
Sturtevant, Robert B., University of N. Dakota
Stverak, Louis J., University of South Dakota
Suetholz, Frank H., Jr., Purdue University
Surfus, Virgil L., Ore. Agricultural College
Sutherland, John H., Virginia Military Institute
Swetonic, Stephen A., University of Pittsburgh
Takemoto, Arthur M., University of California
Tapy, Ralph W., Rose Polytechnic Institute
Tarbell, Kenneth D., Northeastern University
Taylor, Dale W., University of Colorado
Teagarden, E. Wallace, University of Colorado
Teele, John W., Harvard University
Terry, Clifford B., Mass. Institute of Technology
Thomander, Veron S., University of Utah
Thorne, Robert R. M., University of Pittsburgh
Thornton, James F., Marquette University
Tovar, Carlos, Jr., Escuela de Ingenieros Mecanicos y Electricistas
Tuttle, Arthur N., University of Colorado
Trainer, Merrill A., Drexel Institute
Tucker, Cary S., University of Kentucky
Tunks, J. William, University of Kentucky
Tuttle, Vernon B., State University of Iowa
Twomey, Edward J., Catholic University of America
Tyack, Leroy C., Northeastern University
Tyrrell, Laurance E., Iowa State College
Umhoefer, J. A., Iowa State College
Utt, Joseph H., Rose Polytechnic Institute
Vasauskas, Stanley, Clarkson College of Technology
Vincent, Walter N., Cornell University
Wacker, Herman A., State University of Iowa
Wagner, Charles N., Jr., Lehigh University
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Wagner, Herman H., Iowa State College
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Wallace, C. J., California Institute of Technology
Walsh, Bruce R., Rose Polytechnic Institute
Walters, Edward W., University of Kentucky
Ward, Albert N., Kansas State Agricultural College
Ware, Lawrence A., State University of Iowa
Watkins, Robert H., Syracuse University
Watson, C. Wilbur, Lehigh University
Watson, Harold E., University of Colorado
Watts, D. E., Iowa State College
Webber, Leo T., Iowa State College
Weber, Ralph C., California Institute of Technology
Weingartner, J. A., University of Kentucky
Weller, Albert O., Drexel Institute
Wells, John S., Rose Polytechnic Institute
Werner, Daniel R., Rose Polytechnic Institute
Weston, Irving L., Northeastern University
Weston, Joseph R., University of Utah
Wheeler, G. L., University of Oklahoma
Wheeler, Robert C., University of California
Whelan, Laverne B., Michigan State College
White, Samuel D., Rutgers University
White, Stewart H., Washington State College
Wicht, Harold L. P., University of Colorado
Wiebrecht, Francis E., Kansas State Agricultural College
Wilcox, Stanley H., Rutgers University
Williams, Dexter B., Clarkson College of Technology
Williams, H. P., University of Washington
Wilson, Joe, University of Colorado
Wing, Wendell C., Ore. Agricultural College
Winter, Francis E., McGill University
Witty, Maurice L., Rose Polytechnic Institute
Wolfe, H. C., University of Wisconsin
Wolfe, William F., Purdue University
Woodcock, Virgil E., Ore. Agricultural College
Woods, Howard O., Mass. Institute of Technology
Woolridge, Clarence E., State University of Iowa
Worthington, Carol N., Alabama Polytechnic Institute
Woy, Frank H., University of Wisconsin
Wright, John L., Alabama Polytechnic Institute
Wright, Stanley J., University of Washington
Wright, Thomas J., Lehigh University
Yarline, Frank W., University of Illinois
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Washington, D. C.	A. F. E. Horn	L. E. Reed, Potomac Elec. Pr. Co., 14th & C Sts., N. W., Washington, D. C.
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Yale Univ., New Haven, Conn.	S. A. Tucker	G. C. Bailey

Total 83

DIGEST OF CURRENT INDUSTRIAL NEWS

NEW CATALOGUES AND OTHER PUBLICATIONS

Mailed to interested readers by issuing companies.

Splices and Tapes.—Bulletin, 16 pp. Describes splices and tapes for rubber insulated wires. Instructions for making a perfect joint are included. The Okonite Company, Passaic, N. J.

Voltage Regulators.—Bulletin GEA-123, 60 pp. Describes various types of automatic voltage regulators for practically every requirement. General Electric Company, Schenectady, N. Y.

Effect of Power Factor.—The October issue of "The Delta Star," issued by the Delta Star Electric Company, 2400 Block Fulton Street, Chicago, has a very complete article entitled "Effect of Power Factor on the Capacity and Regulation of Transmission Lines and Generating Equipment," by E. J. Kallevang.

Wire Cables for Suspension Bridges.—Bulletin, 96 pp. Describes the construction of parallel wire cables for suspension bridges, and includes a large number of striking photographs of the Bear Mountain Bridge across the Hudson River in various stages of erection. John A. Roebling's Sons Company, Trenton, N. J.

History of Gas Service in Chicago.—"75 Years of Gas Service in Chicago" is the title of a book, 58 pp., by Wallace Rice, issued by the Peoples Gas Light & Coke Company, Chicago, Ill. It is an interesting account of the origin and growth of the gas industry in Chicago.

Lubrication of Electric Motors.—The October issue of "Lubrication," the monthly bulletin published by the Texas Company, 17 Battery Place, New York, contains a comprehensive, illustrated article on various electric motor bearing lubricating systems in common use, with an analysis of the characteristics of the respective lubricants required.

New Motor Drive.—Bulletin 1228, 16 pp. Describes the Allis "Texrope" drive, a new flexible and positive multiple belt drive for close centers. The "Texrope" drive consists of two grooved sheaves, and a number of specially constructed endless "V" belts. The advantages claimed for the new drive include absence of slip, back lash or lost motion, extreme smoothness of starting and running, together with small space requirement. The Allis-Chalmers Mfg. Company, Milwaukee, Wis.

C. M. & St. P. Electrification.—Bulletin GEA-150, 44 pp. The progress in electrification accomplished by the Chicago, Milwaukee & St. Paul Railroad is described. Profusely illustrated, the book takes up in detail all of the equipment, including locomotives, substations, power supply, and transmission and overhead construction. In addition to photographs of equipment, there are numerous maps, diagrams and tables of specifications. Figures are presented to show the comparative cost of electric and steam operation. General Electric Company, Schenectady, N. Y.

NOTES OF THE INDUSTRY

The Kuhlman Electric Company, Bay City, Mich., has recently contracted for an addition to its present factory. This addition will measure approximately 75 feet by 250 feet and in the new building the Kuhlman Company is preparing to construct the larger sizes of transformers.

The Southern Power Company, will erect a new steam station of 100,000 h. p. capacity. The location for the new station has not yet been announced, but the plans for the equipment have been made. Two 35,000 kw. steam turbine generators manufactured by the General Electric Company will be installed.

The Killark Electric Mfg. Company, St. Louis, Mo., is erecting a new factory building at 3940 Easton Avenue, covering about 25,000 sq. ft., of the latest type reinforced concrete. The entire factory will be on one floor so as to eliminate the use of elevators. The new building will be completed in January 1926. The Company manufactures Electrolet conduit fittings, bell ringing transformers and enclosed fuses.

The Roller-Smith Company, 12 Park Place, New York, announces that its Knoxville, Tenn., agent, the Tennessee Engineering & Sales Company, has opened a branch office at 493 No. Boulevard, Atlanta, and all Georgia business will be looked after from the Atlanta office. The New England agency of the Roller-Smith Company, the Detweiler-Bell Company, now has its main office at 101 Milk Street, Boston, and a branch office at 152 Temple Street, New Haven, Conn. Paul G. Detweiler and R. H. McCormick are located in the Boston office, and F. M. Lord is in the New Haven office.

The Southern California Edison Company has already completed plans for the addition of a 50,000 kw. turbine generator to the equipment of its new Long Beach steam station at Power, Cal., opened only a year ago, because of the rapid growth of the demand for electrical power. The unit will be the largest ever shipped beyond the Rocky Mountains; the previous record was held by the two 35,000 kw. turbines installed in this station last year. The new turbine is being built by the General Electric Company, which also furnished the original units, and shipment will be made within eight months. In the summer months natural gas is used as fuel. In the cooler months when there is an increased demand for the gas for other purposes, fuel oil is used for steam generation.

Adjustable Adapter to fit Small Radio Tubes into Large Sockets. With the advent of the small type base tubes, there are occasions when it is desirable to employ these small base tubes in standard sockets of receiving sets. To facilitate such procedure the Pacent Electric Company, 71 Seventh Avenue, New York, has introduced a special adapter which takes a small base tube and adapts it for use in any standard socket, thus making available the high efficiency of present-day dry battery tubes, together with their low current consumption. The new Pacent adapter consists of a shell of Isolantite, with four holes, one larger than the other three, to take the four prongs of the small base tube. A lock screw securely holds the tube in the adapter for ready handling, while a pin assures proper engagement with the bayonet slot of the usual socket.

Hearing on Water Power Permits.—A public hearing will be held in the Auditorium, Chattanooga Manufacturer's Association, 815 Broad Street, Chattanooga, Tenn., at 9:30 a. m., December 15, for the purpose of enabling those interested to present to the United States District Engineer such statement of fact or opinion as it is believed should be considered in connection with the pending applications for preliminary permits for the construction of certain power and power-navigation dams on the Tennessee River above Chattanooga, and on the Clinch and Powell Rivers. The following applications are pending:

By the Tennessee Hydroelectric Company (5); proposed installations totalling 340,000 h. p.

By the Tennessee Electric Power Company (3); proposed installations totalling about 177,000 h. p.

The Knoxville Power & Light Company (6); proposed installations totalling about 321,500 h. p.

The East Tennessee Development Company (11); proposed installations totalling about 592,500 h. p.

All statements and arguments should be submitted in writing to the presiding officer, as far as possible. The question of land damages resulting from the execution of the proposed projects is a matter for settlement between parties concerned, or for adjudication under State law. It does not come within the jurisdiction of the Federal Power Commission and will not be considered at this hearing.


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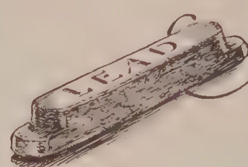

Mineral

It took three kingdoms ...and one republic

– to make your telephone

The silkworm of the animal kingdom, the cotton plant of the vegetable kingdom, and the lead bar of the mineral kingdom—these are typical of the nineteen different raw materials which America's technical genius has compounded into the telephone.

TO the making of your telephone, Nature's three great kingdoms—animal, vegetable and mineral—have contributed generously. And, to these, the American republic has given of its best inventive vision and work-a-day skill.

This has been an enterprise reaching to the far places of the earth but coming back always to the Western Electric telephone factory at Chicago.

Here precious gold and shining silver are matched in brilliance by the ingenuity that directs their use. Here too age-old traditions in the culture of silk are met by modern methods in the production of the telephone.

In less than half a century Western Electric men have made these methods the standard of the world for telephone making.

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THE lessened cost of maintenance of electric motors when equipped with New Departure Ball Bearings amounts to a substantial saving on the original investment.

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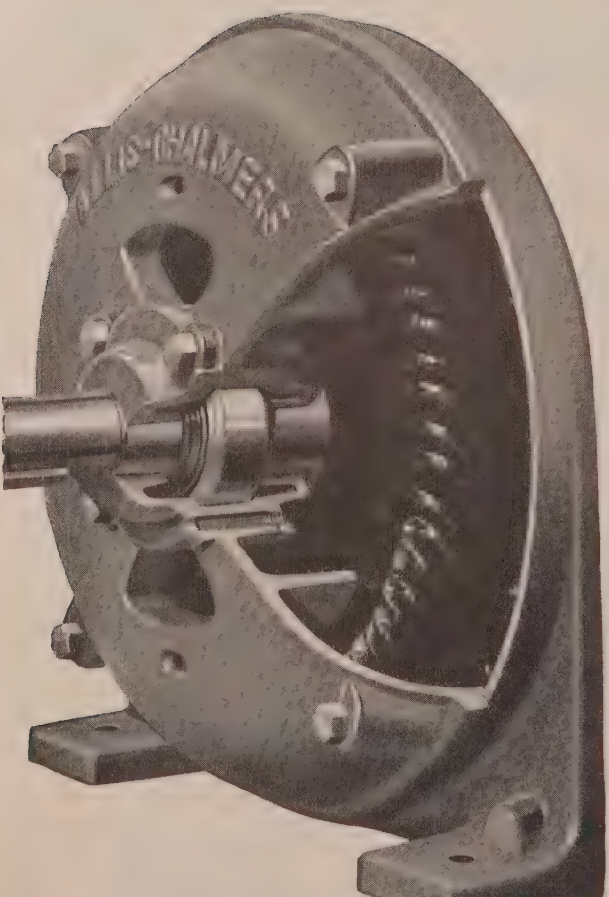

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Into Allis-Chalmers motors have been incorporated the typical advantages of tapered roller bearings, so completely endorsed in dozens of other exacting applications. Friction at a minimum, lubrication at rare intervals, permanent alignment, protection from thrust and shock—these coveted betterments are now obtainable in Allis-Chalmers induction motors.

Add such well known Allis-Chalmers refinements as electric steel frames, distortionless cores, silver-brazed rotor bars and uniform cooling. The result is a motor that expresses highest development in electric motor design.

Lower cost of operation, negligible upkeep, and security against interrupted service are the logical outcome of latest Allis-Chalmers advancements. A request will bring complete information on Allis-Chalmers roller bearing motors, or on any type of Allis-Chalmers motor.

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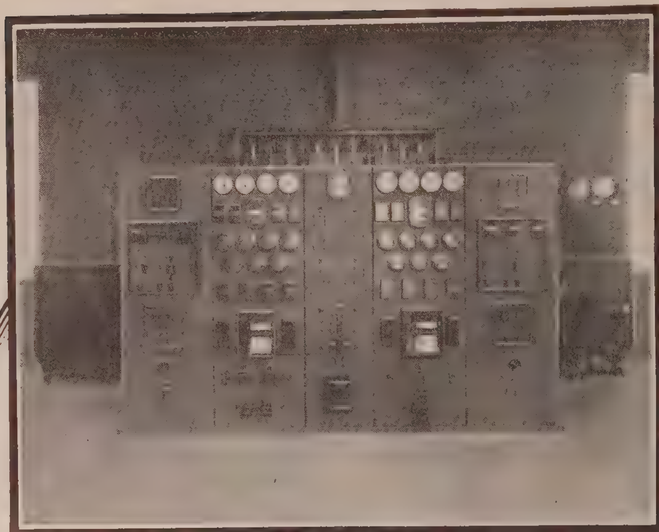

The Switchboard and an Exterior View of the Automatic Generating Station of the Wisconsin Public Service Co. at Johnson Falls, Wisconsin

The Peaks Are Here!

THE season of long nights and short days is here again, bringing its increased demand on the facilities of the central station.

All through the cold evenings the meter dials spin faster and faster. Steadily the load mounts higher and higher. The generators groan in their efforts to keep the system supplied. But at last the load eases up, and ten o'clock finds the generators settling back to their old contented hum, glad once again to return to norma[1] load. Verily, the peaks are here.

Now is the time to find out if you must supply added generating capacity to care for next year's higher peaks.

When added capacity is needed, remember that automatic hydro-electric stations eliminate almost all attendance costs, and permit the economical utilization of power from small streams.

Westinghouse switching equipment for these stations gives the apparatus complete protection against overloads, short circuits, overheated bearings and all other emergencies. And there is a certainty, a precision in its operation assuring the utmost confidence that it will do the right thing at the right time always. It is dependable.

There is a Westinghouse Switchboard Specialist near you who will be glad to give you further details.

Westinghouse Electric & Manufacturing Company
East Pittsburgh Pennsylvania
Sales Offices in All Principal Cities of the United States and Foreign Countries

Westinghouse

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Booths 241 and 242 at the Power Show

Five Perfected Products of Protection

1

Cory Audi-Visible Annunciator

2

Cory Station Load Indicator

1 *Cory Audi-Visible Annunciators* have the feature of warning not only the eye but the ear. Should trouble occur in any part of a plant guarded by this system, a gong would sound and the nature and location of the trouble would be flashed on the board.

2 *The Cory Station Load Indicator* is equipped with a black present load and red expected load pointers. The present load pointer is actuated through a wattmeter and indicates simultaneously any fluctuation, while the expected load pointer is manually actuated from a bench board or panel mounted transmitter. A period light indicator designates the time interval to expected load indicated.

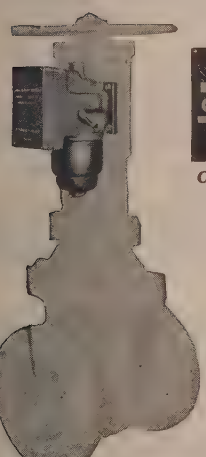
3 *The Cory Turbine Order Signal Systems* provide an instantaneous means of transmitting routine orders. One turn of the transmitting pointer to the desired instruction and the receiving pointer at a distant location instantly moves to the corresponding order on the receiving dial—sounding a gong to attract attention.

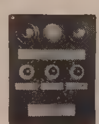
4 *The Cory-Recony Valve Control* meets the four great requirements needed for the successful motor operation of gate valves. They are the Flexibility of change from automatic to remote control—the Adaptability to all sizes and types of new or old valves—the Reliability of a correctly designed product and the Effectiveness which drives a valve through to its seat under power.

5 *The Robinson Switch Interlock* protects workmen from entering bus cells under load until the circuit breaker is open. Furthermore it prevents a remote switchboard operator from turning on the current while a man is working in the cell.

Other Cory Products
Ohmmeters, Flow Meters,
Telephones, Fixtures

CHAS. CORY & SON INC.





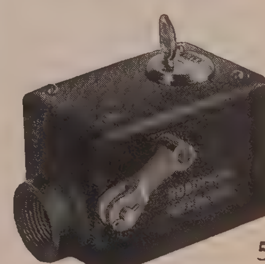
Control Station

4

Cory-Recony Valve Control


3

Cory Turbine Order Signal


5

Robinson Switch Interlock

Cory Service

CORY SAFETY SERVICE TRADE MARK EST. 1840

New York	183 Varick Street
Philadelphia	The Bourse
San Francisco	11 Mission Street
Boston	110 High Street
Chicago	22 W. Quincy St.
Detroit	155 W. Congress St.
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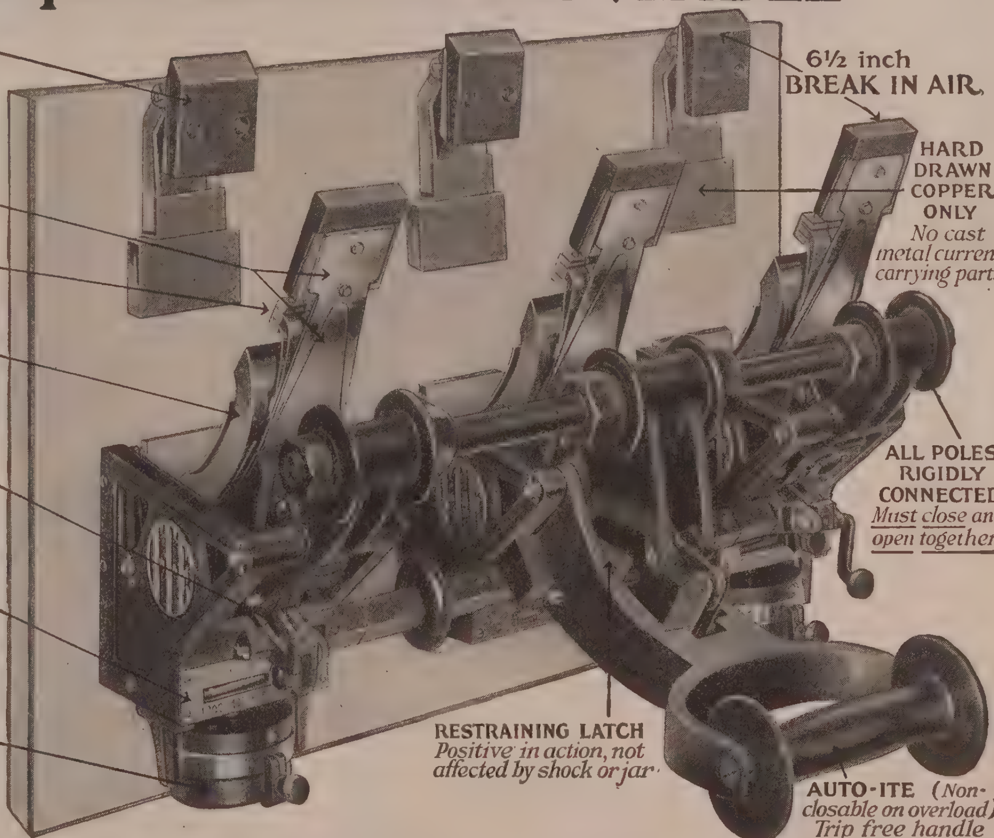
The World's Largest Manufacturer of Signaling, Communicating and Lighting Equipment

AIR!
CIRCUIT BREAKERS
For Alternating Current
600 VOLTS OR LESS
Give protection without complication
All parts accessible and VISIBLE



I-T-E AIR BREAK has definite advantages not present in the oil breaker

1. *No oil — to leak, carbonize, burn or explode — Just air.*
2. *No tanks to conceal anything — or the lack of it.*
3. *No cells — nothing which needs or deserves to be imprisoned — Just a faithful and efficient servant.*
4. *Inherent simplicity — with resulting low cost of installation and maintenance.*

The CUTTER I-T-E COMPANY
ESTABLISHED 1888 PHILADELPHIA

1829 Hamilton Street

In the Pine Tree State~Man's Paradise!

Hydro-Electric Station at Veazie, Maine

River Crossing at Bangor, Maine

Famous Penobscot River Salmon Pool below Veazie Station

The Ellsworth Hydro-Electric Station

THE Bangor Hydro-Electric Company supplies electric service to three of the most easterly counties in the State of Maine. The hydro-electric station of the Company located at Veazie, Maine, was the third plant of its kind to be constructed in the United States.

The transmission line, built on Locke Pin Type Insulators, connecting the Veazie and Ellsworth stations, is operated at the highest potential in the State of Maine, 50,000 volts. The dam at the Ellsworth generating station was the first high Ambursen Dam constructed in this country. The height of this dam is 61 ft.

Owing to the diversity of water conditions on the two river systems, the Penobscot and Union Rivers, no steam reserve whatever is maintained by this Company.

The principal industries served by this Company are pulp and paper, lumber, and textile products.

This system, built and maintained with Locke Porcelain Insulators, represents one of the many hundreds of pioneer electrical developments whose service has expanded with the rapid growth of American Industry—even as Locke Porcelain, the first ever used for electrical insulation, has maintained its leadership in its service to the Electrical Industry.

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***Export Agents:* International General Elec. Co., Schenectady, N. Y.**

LOCKE PORCELAIN

Cut~ Installation Time *in Half!*

When you consider the amount of money paid for installing anchors and figure that this can be reduced greatly by using Matthews Scrulix Anchors you can readily see why they are in big favor by many companies.

Test on top of famous Missionary Ridge in heavy disintegrated rock

Two men with Matthews Earth Auger, made complete installation of No. 612-R 6 inch anchor in 14 minutes. Ten minutes for auger hole 1 man, 4 minutes for screwing anchor down 5 feet 6 inches. Total of 18 minutes on one man basis. In attempting to pull up anchor a tree 16 inches in diameter was nearly pulled over. Engineers were all astonished at results and ability to install in this ground.

Cut down your anchor costs by using Matthews Scrulix Anchors.

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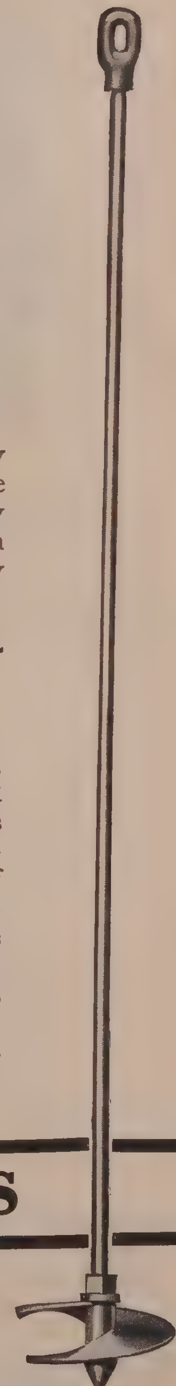

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Matthews Scrulix Anchors are made in 7 sizes
There is a size for every anchor requirement.

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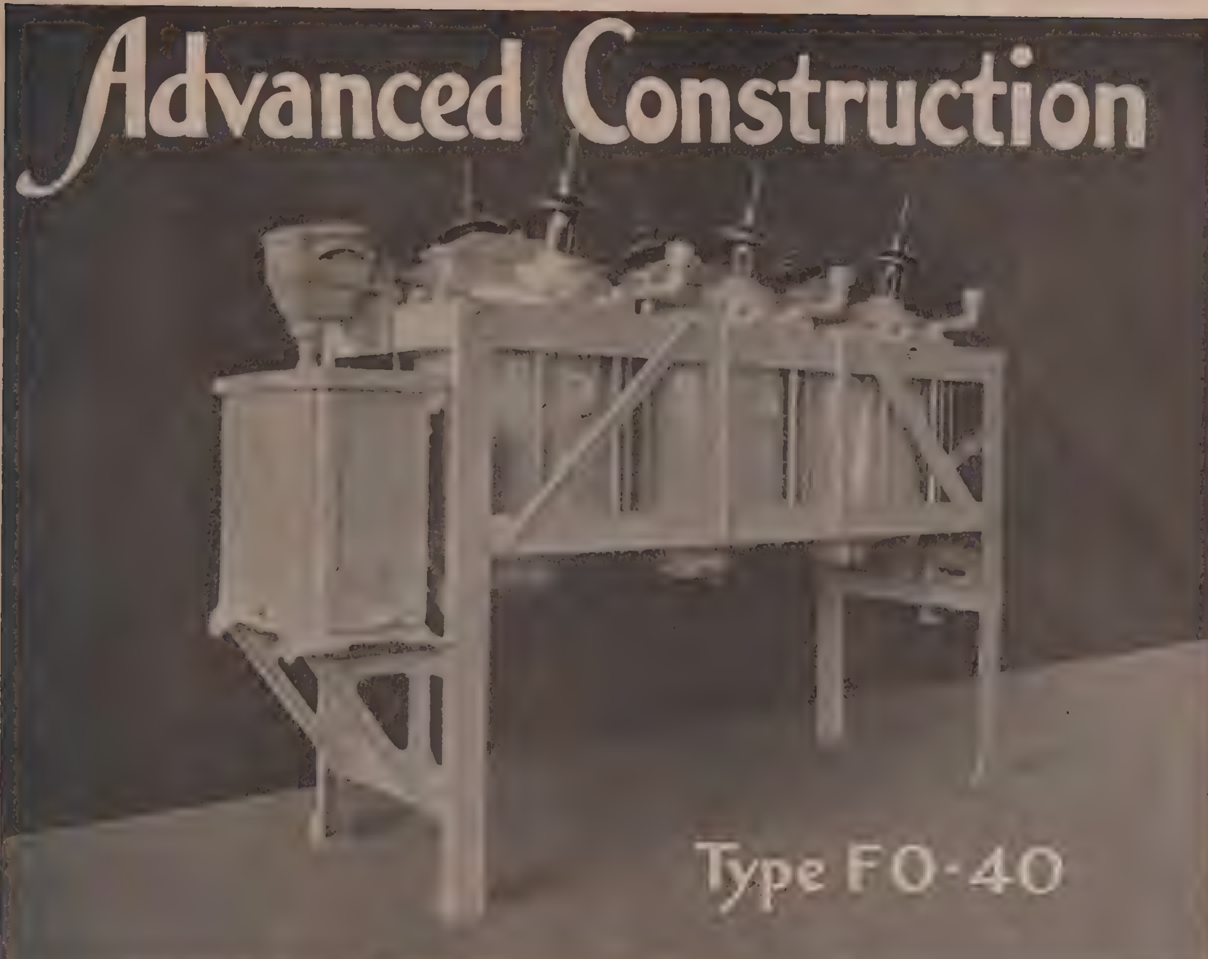

Massive steel pole tops—cylindrical tanks with heavy dished bottoms—rugged frame construction—high speed of circuit interruption—for higher voltage super power developments.

For further information

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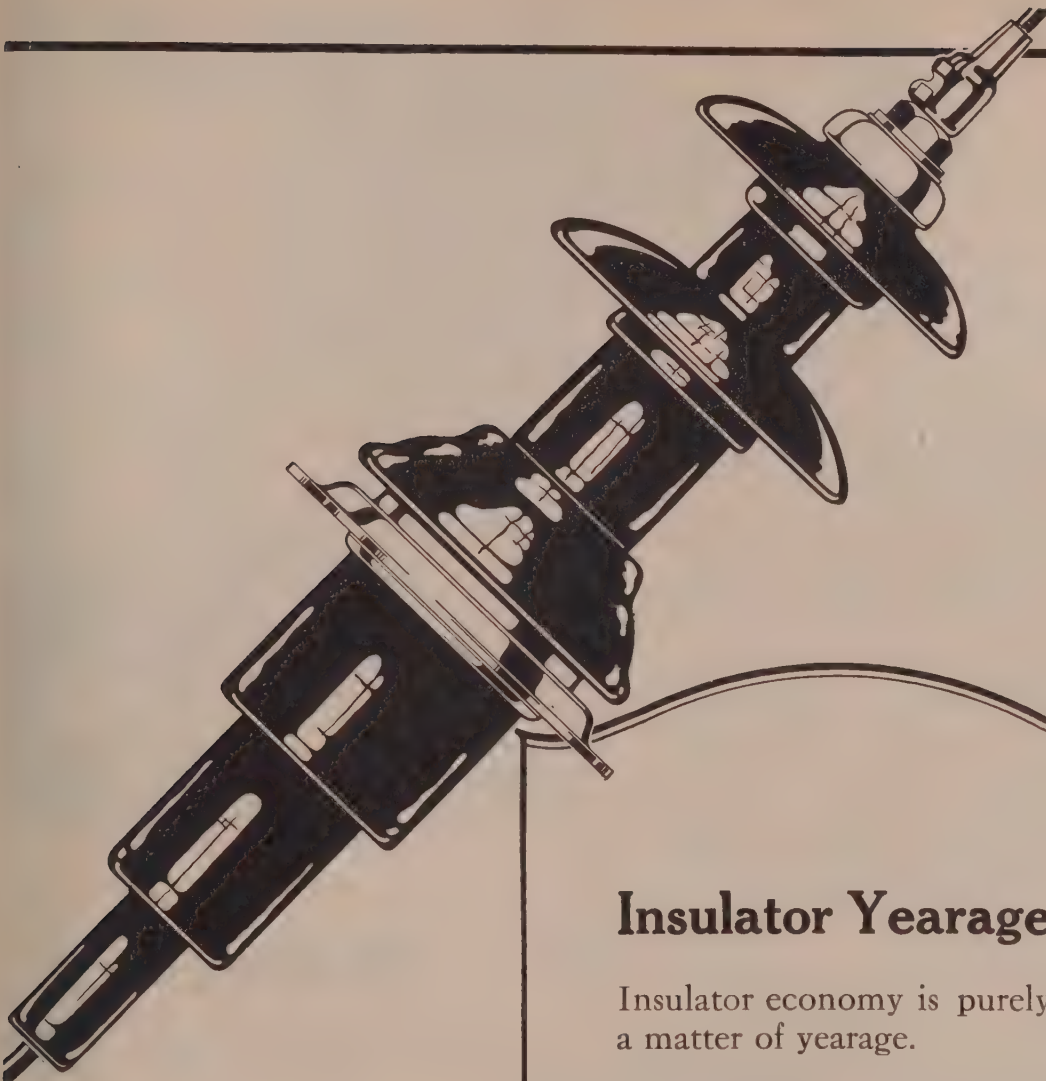

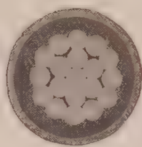

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SIMCORE - National Electrical Code Standard. Every length is subjected to searching electrical tests to insure a first quality product. Ask for specifications.
CAOUTCHOUC - "B. C." A rubber covered braided wire insulated with a 30% Para compound. Send for specifications.
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TIREX MINING MACHINE CABLES - Heavily insulated, rubber-armored, portable cables with the wearing qualities of a cord tire.
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ARC CABLE - For connecting swinging arc lamps with transmission lines.
AUTOMOBILE - Wires and cables for lighting and ignition systems.
RUBBER INSULATED CABLES - For any commercial voltage. Special descriptive bulletin on request.
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SPECIAL INSULATED WIRES AND CABLES - To meet any conditions of service. On specification drawn by our engineers or to conform to customers' specifications.

Technically trained experts who know how to impart the qualities which insure satisfactory service supervise the manufacture of all Simplex Wires and Cables.

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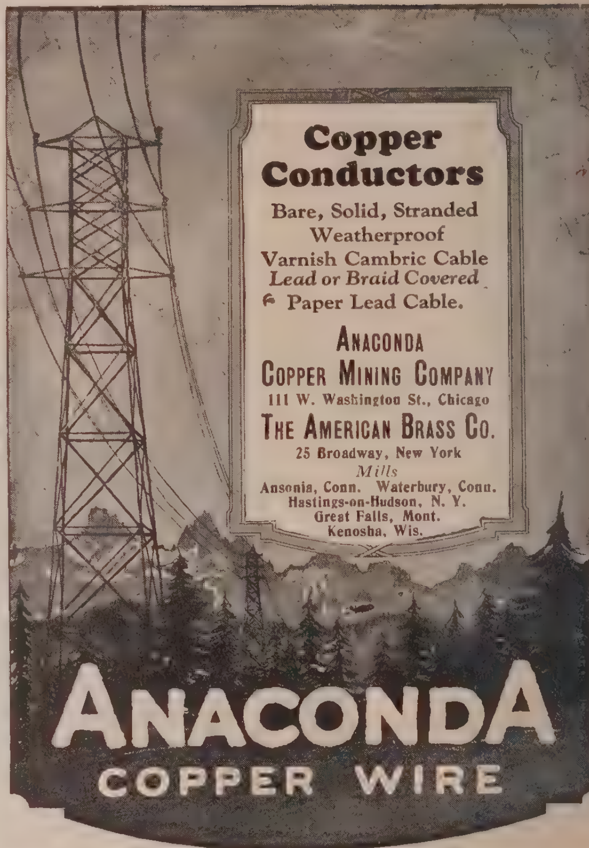

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Reliability — Long Life

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Fire alarm service demands the utmost reliability because of its very nature. The most reliable source of power is a storage battery charged by an apparatus which requires no adjustment and a minimum of attention.

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Balkite Rectifier Cells and Balkite Transformers are designed to charge the various voltage batteries used in fire alarm systems at the proper charging rates.

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- ☐ Time Recording Systems
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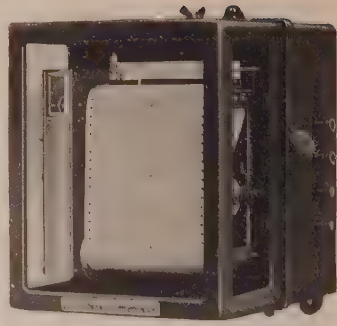

Equally Valuable for Testing Feeder Loads or Motors

Bristol's Recording Wattmeter

is important to record load fluctuations and especially the variation from hour to hour and from day to day.

Bristol's Recording Wattmeters are available for alternating or direct current and for single, two or three phase current, and furnished in round as well as strip chart models in switchboard and portable cases.

Ask for Bulletins BC-1501 and 332.

THE BRISTOL COMPANY
Waterbury, Connecticut

Jagabi Type C Hand Tachometers

are widely used for measuring speeds of Motors, Generators, Fans, Engines, Belts, Shafting, etc. They read directly in r.p.m. and are independent of the direction of rotation. The dial is three inches in diameter and the scale is easily read. Type C Tachometers are built for speeds as low as 30 and as high as 24,000 r.p.m.; with one, three and four speed ranges.

Bulletin 1025-J on request

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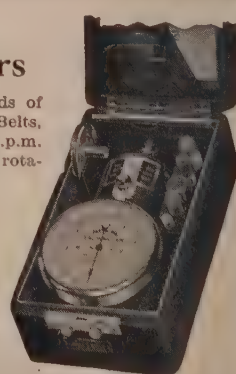

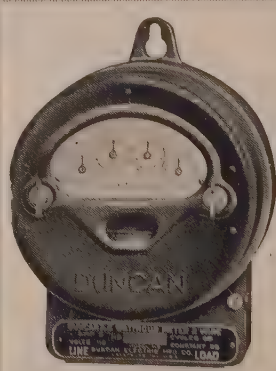

Duncan Model M2.

An A. C. Watthour meter that for accuracy, efficiency and low cost up-keep is without a peer. Its design represents perfection in every detail and central stations are loud in their praises concerning its dependability.

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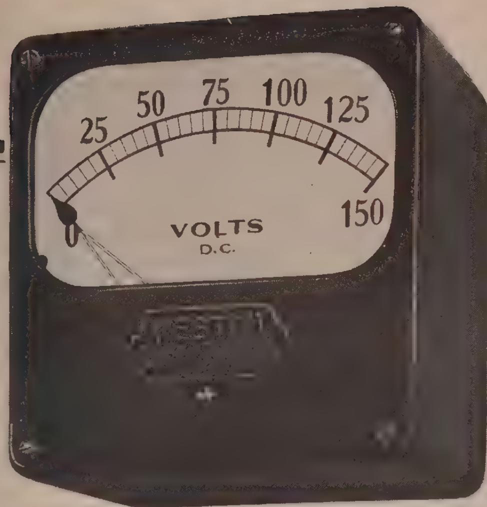

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ENGINEERS from coast to coast are availing themselves of the savings in switchboard space made possible by Weston Rectangular instruments.

These Weston Rectangulars have been accepted everywhere because the leading men in the various electrical fields have long been looking for a solution to the reduction of switchboard space without a loss of instrument efficiency.

Weston dependability, accuracy and precision assembly hold good throughout. The famous Weston movement has simply been enclosed in a new case—which has already revolutionized modern switchboard design.

Longer scales, greater legibility and extreme accessibility for maintenance are found in this new Weston line.

Weston rectangulars are available in A. C. Ammeters, Voltmeters, Wattmeters, Frequency Meters, Power Factor Meters and Triplex Ammeters, and D. C. Voltmeters and Ammeters.

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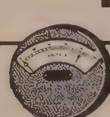

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VOLT-AMMETER

A combination instrument that you cannot afford to be without

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THE ROLLER-SMITH GSD instruments are recognized in every industry as much needed aids to efficiency. This GSD Volt-ammeter is a real combination portable D. C. Volt-ammeter that takes up the space of only one instrument and yet costs much less than two separate instruments. Of convenient size, lightweight, rugged and—above all—accurate and reliable, it does double the work—for only a little more than half the investment.

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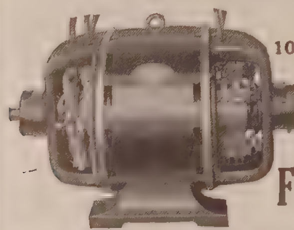

10% BETTER EFFICIENCY
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100% POWER FACTOR

Sizes 1½ KW to 50 KW with control panel. To convert from any voltage AC to any desired voltage DC.

FOR INDUSTRIAL PURPOSES
BATTERY CHARGING
MOTION PICTURES

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NORTHWESTERN ELECTRIC COMPANY
Also Mfrs. of "AK" Variable Speed A. C. Motors
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MODELS

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MANUFACTURING STANDARDS
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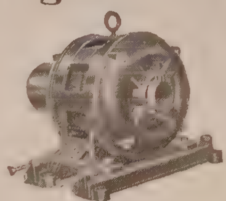
Incorporated 1897

Star Ball Bearing Motors

For Hard Usage
—
A. C. and D. C.



Complete line of standard motors and generators, all sizes up to 75 h.p. and 50 kw. respectively.

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Sturtevant Electric Motors

—A. C. and D. C.; single and polyphase—built in sizes from small fractional to 250 horse-power—designed to operate under a constant full load where uninterrupted service is demanded.

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Small Motors, Generators, Dynamotors, Motor Generators, Rotary Converters, Etc.

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(1) To determine the quality of competing samples. This enables the purchase of the best quality for the money.
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Testing places the whole buying problem on a sound basis.

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Morganite Brush Co., Inc.
519 W. 38th St.
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"They Keep a-Running"

7½ Horse Power Century Squirrel-Cage Polyphase Induction Motor

Armatures Are Practically Indestructible

The armatures of Century Squirrel-cage Polyphase Induction Motors are practically indestructible—first, because all materials entering their construction are liberally proportioned and, second, because they are assembled to mechanical standards that assure long life under severe service conditions.

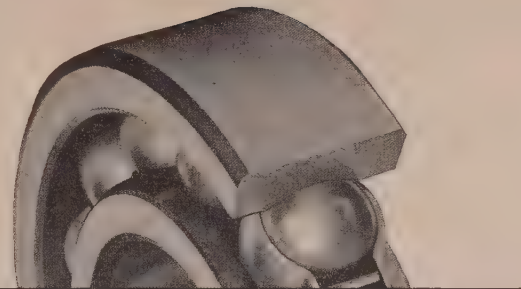
1. Armature laminations are accurately stamped from highest grade steel sheets, annealed and assembled into a rigid unit.
2. Conductor bars are cut from commercially pure drawn copper of generous cross section to provide high conductivity and ample mechanical strength.
3. End rings in the ½ horse power and larger sizes are of channel-section copper, punched to receive the conductor bars, and are brazed to them over an area equal to about six times the cross sectional area of the bars.
4. Sheet steel fans provide ample ventilation under all operating conditions.

Century Squirrel-cage Induction Polyphase Motors are built in all standard sizes from ¼ to 50 horse power. Temperature rise not more than 40° Centigrade. Send for form No. 536 and Bulletin No. 38 describing Century Squirrel-cage Induction Polyphase Motors.

Century Electric Co.
1806 Pine St. St. Louis, Mo.

For More Than 22 Years at St. Louis

¼ to 50 H. P. Century MOTORS ¼ to 50 H. P.



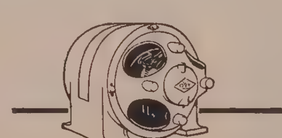
Twenty years' service couldn't make them show wear

IN a Pittsburgh steel mill they dismantled for repairs an electric motor which had given continual service for twenty years.

When they came to the "SRB" ball bearings, it was found they were in *perfect condition*—after twenty years!

This is an exceptional performance, but it shows how thoroughly ball bearings will protect against scored shafts, damaged rotors and windings and frequent bearing replacements with motor shut-downs.

Even greater load carrying capacity and durability are obtained through our recent adoption of forged Molybdenum Steel Balls. Large sizes available—others in process.



Standard Steel and Bearings Incorporated

Plainville USE SRB BALL BEARINGS-*First!* *—they'll last* **Connecticut**

2549

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April, May, June, 1925

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AMERICAN INSTITUTE of ELECTRICAL ENGINEERS
33 West 39th Street, New York

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Manufacturers and agents for machinery and supplies used in the electrical and allied industries.

Note: For reference to the Advertisements see the Alphabetical List of Advertisers on page 44.

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General Electric Co., Schenectady
Western Electric Co., All Principal Cities

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Minerallac Electric Co., Chicago

AMMETER, VOLTMETERS
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ANCHORS, GUY
Matthews Corp., W. N., St. Louis

ANNUNCIATORS, AUDIO-VISIBLE
Cory & Son, Inc., Chas., New York

BATTERY CHARGING APPARATUS
Electric Specialty Co., Stamford, Conn.
Fansteel Products Co., Inc., North Chicago
General Electric Co., Schenectady
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BEARINGS, BALL
Fafnir Bearing Co., New Britain, Conn.
Marlin-Rockwell Corp., Chicago
New Departure Mfg. Co., The, Bristol, Conn.
Norma-Hoffmann Bearings Corp., Stamford, Conn.
Standard Steel & Bearings, Inc., Plainville, Conn.

BOXES, FUSE
General Electric Co., Schenectady
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., Pittsburgh

BOXES, JUNCTION
G & W Elec. Specialty Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Standard Underground Cable Co., Pittsburgh

BRUSHES, COMMUTATOR
Carbon
Morganite Brush Co., Inc., New York
National Carbon Co., Inc., Cleveland
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Copper Graphite
Morganite Brush Co., Inc., New York
National Carbon Co., Inc., Cleveland
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

BUS BAR FITTINGS
Burndy Engineering Co., Inc., New York
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CABLE ACCESSORIES
Delta-Star Electric Co., Chicago
Dossert & Co., New York
G & W Electric Specialty Co., Chicago
General Electric Co., Schenectady
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

CABLES
(See WIRES AND CABLES)

CABLEWAYS
American Steel & Wire Co., Chicago
Roebling's Sons Co., John A., Trenton, N. J.

CAMBRIC, VARNISHED
Belden Mfg. Co., Chicago
Irvington Varnish & Ins. Co., Irvington, N. J.

CIRCUIT BREAKERS
Air—Enclosed
Cutter Co., The, Philadelphia
Roller-Smith Co., New York
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N. Y.
Western Electric Co., All Principal Cities
Oil
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CLAMPS, GUY & CABLE
Burndy Engineering Co., Inc., New York
Matthews Corp., W. N., St. Louis

COILS, CHOKE
Burke Electric Co., Erie, Pa.
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COILS, MAGNET
Belden Mfg. Co., Chicago
Dudlo Mfg. Corp., Ft. Wayne, Ind.
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDENSATION PRODUCTS
Bakelite Corporation, New York

CONDENSERS, RADIO
Dubilier Condenser & Radio Corp., New York
General Radio Co., Cambridge, Mass.
Pacent Electric Co., New York

CONDENSERS, STEAM
Allis-Chalmers Mfg. Co., Milwaukee
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONDUIT, UNDERGROUND FIBRE
Western Electric Co., All Principal Cities

CONNECTORS, SOLDERLESS
Dossert & Co., New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONNECTORS AND TERMINALS
Belden Mfg. Co., Chicago
Burke Electric Co., Erie, Pa.
Burndy Engineering Co., Inc., New York
Dossert & Co., New York
G & W Electric Specialty Co., Chicago
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONTACTS, TUNGSTEN
Fansteel Products Co., Inc., North Chicago
General Electric Co., Schenectady

CONTROL SYSTEMS
Ward Leonard Electric Co., Mt. Vernon, N.Y.

CONTROLLERS
General Electric Co., Schenectady
Rowan Controller Co., Baltimore
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

CONVERTERS—SYNCHRONOUS
Allis-Chalmers Mfg. Co., Milwaukee
Electric Specialty Co., Stamford, Conn.
Northwestern Electric Co., Chicago
Wagner Electric Corp., St. Louis
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

COOLING PONDS
Spray Engineering Co., Boston

COPPER CLAD WIRE
Belden Mfg. Co., Chicago
Copperweld Steel Co., Rankin, Pa.
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

CUT-OUTS
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
G & W Electric Specialty Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

DIMMERS, THEATRE
Ward Leonard Electric Co., Mt. Vernon, N.Y.

DYNAMOS
(See GENERATORS AND MOTORS)

DYNAMOTORS
Burke Electric Co., Erie, Pa.
Electric Specialty Co., Stamford, Conn.

ELECTRIFICATION SUPPLIES, STEAM ROAD
General Electric Co., Schenectady
Ohio Brass Co., Mansfield, Ohio
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ENGINEERS, CONSULTING AND CONTRACTING
(See PROFESSIONAL ENGINEERING DIRECTORY)

ENGINES
Gas & Gasoline
Allis-Chalmers Mfg. Co., Milwaukee
Sturtevant Company, B. F., Boston
Oil
Allis-Chalmers Mfg. Co., Milwaukee
Sturtevant Company, B. F., Boston
Steam
Allis-Chalmers Mfg. Co., Milwaukee
Sturtevant Company, B. F., Boston

FANS, MOTOR
Century Electric Co., St. Louis
General Electric Co., Schenectady
Star Electric Motor Co., Newark, N. J.
Sturtevant Company, B. F., Boston
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FARM LIGHTING GENERATORS
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FIBRE
Belden Mfg. Co., Chicago
National Vulcanized Fibre Co., Wilmington, Del.

FLOW METERS
Cory & Son, Inc., Chas., New York
General Electric Co., Schenectady
Spray Engineering Co., Boston

FURNACES, ELECTRIC
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

FUSES
Enclosed Refillable
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Enclosed Non-Refillable
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Open Link
General Electric Co., Schenectady
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
High Tension
Delta-Star Electric Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities

GEARS, FIBRE
General Electric Co., Schenectady
National Vulcanized Fibre Co., Wilmington, Del.

GENERATORS AND MOTORS
Allis-Chalmers Mfg. Co., Milwaukee
Burke Electric Co., Erie, Pa.
Century Electric Co., St. Louis
Chandeysson Electric Co., St. Louis
Electric Specialty Co., Stamford, Conn.
Electro-Dynamic Co., Bayonne, N. J.
General Electric Co., Schenectady
Northwestern Electric Co., Chicago
Star Electric Motor Co., Newark, N. J.
Sturtevant Company, B. F., Boston
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GENERATING STATION EQUIPMENT
Allis-Chalmers Mfg. Co., Milwaukee
Burke Electric Co., Erie, Pa.
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

GROUND RODS
Copperweld Steel Co., Rankin, Pa.
Western Electric Co., All Principal Cities

HEADLIGHTS
Ohio Brass Co., Mansfield, O.

HEATERS, INDUSTRIAL
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

INDICATORS, LOAD
Cory & Son, Inc., Chas., New York

INDICATORS, SPEED
Biddle, James G., Philadelphia
Roller-Smith Co., New York

INDICATORS, WATER LEVEL
Cory & Son, Inc., Chas., New York

INSTRUMENTS, ELECTRICAL
Graphic
Biddle, James G., Philadelphia
Bristol Co., The, Waterbury, Conn.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Indicating
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Jewell Elec. Instrument Co., Chicago
Roller-Smith Co., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Corp., Newark, N. J.
Integrating
Biddle, James G., Philadelphia
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Roller-Smith Co., New York
Sangamo Elec. Co., Springfield, Ill.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Radio
General Radio Co., Cambridge, Mass.
Jewell Elec. Instrument Co., Chicago
Repairing and Testing
Electrical Testing Laboratories, New York
Jewell Elec. Instrument Co., Chicago

Classified Advertiser's Index for Buyers—*Continued*

INSTRUMENTS, ELECTRICAL—*Continued*
Scientific, Laboratory, Testing
Biddle, James G., Philadelphia
General Electric Co., Schenectady
Jewell Elec. Instrument Co., Chicago
Metropolitan Device Corp., Brooklyn, N. Y.
Roller-Smith Co., New York
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Weston Elec. Inst. Corp., Newark, N. J.
Telegraph
Western Electric Co., All Principal Cities

INSULATING MATERIALS
Board
West Va. Pulp & Paper Co., New York
Cloth
Irvington Varnish & Ins. Co., Irvington, N.J.
Minerallac Electric Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Composition
American Lava Corp., Chattanooga
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Compounds
Minerallac Electric Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities
Fibre
National Vulcanized Fibre Co., Wilmington, Del.
West Va. Pulp & Paper Co., New York
Lava
American Lava Corp., Chattanooga, Tenn.
Mica
New England Mica Co., Waltham, Mass.
Paper
Irvington Varnish & Ins. Co., Irvington, N. J.
Tullis, Russell & Co., Ltd., London, Eng.
Silk
Irvington Varnish & Ins. Co., Irvington, N. J.
Tape
Belden Mfg. Co., Chicago
Minerallac Electric Co., Chicago
Okonite Co., The, Passaic, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Varnishes
General Electric Co., Schenectady
Irvington Varnish & Ins. Co., Irvington, N. J.
Minerallac Electric Co., Chicago

INSULATORS, HIGH TENSION
Composition
General Electric Co., Schenectady
Glass
Hemingray Glass Co., Muncie, Ind.
Porcelain
General Electric Co., Schenectady
Lapp Insulator Co., Inc., LeRoy, N. Y.
Locke Insulator Corp., Baltimore
Ohio Brass Co., Mansfield, O.
Thomas & Sons Co., R., East Liverpool, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Post Type
Delta-Star Electric Co., Chicago

INSULATORS, TELEPHONE & TELEGRAPH
Hemingray Glass Co., Muncie, Ind.
Western Electric Co., All Principal Cities

LAMP GUARDS
Matthews Corp., W. N., St. Louis
Western Electric Co., All Principal Cities

LAVA
American Lava Corp. Chattanooga

LIGHTING FIXTURES
Cory & Son, Inc., Chas., New York

LIGHTNING ARRESTERS
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

LOCOMOTIVES, ELECTRIC
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

METERS, ELECTRICAL
(SEE INSTRUMENTS, ELECTRICAL)

MICA
New England Mica Co., Waltham, Mass.

MOLDED INSULATION
Bakelite Corporation, New York
Belden Mfg. Co., Chicago
Burke Electric Co., Erie, Pa.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

MOLYBDENUM
Fansteel Products Co., Inc., North Chicago

MOTORS
(See GENERATORS AND MOTORS)

OHMMETERS
Cory & Son, Inc., Chas., New York
Jewell Elec. Instrument Co., Chicago
Roller-Smith Co., New York
Weston Elec. Instr. Corp., Newark, N. J.

OIL SEPARATORS & PURIFIERS
DeLaval Separator Co., The, New York
Sharples Specialty Co., The, Philadelphia
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

PANEL BOARDS
(See SWITCHBOARDS)

PATENT ATTORNEYS
(See PROFESSIONAL ENGINEERING DIRECTORY)

PLUGS
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

POLES, STEEL
American Bridge Co., Pittsburgh
Pacific Coast Steel Co., San Francisco
Western Electric Co., All Principal Cities

POLES—TIES, WOOD
Western Electric Co., All Principal Cities

POTHEADS
G & W Electric Specialty Co., Chicago
Standard Underground Cable Co., Pittsburgh
Western Electric Co., All Principal Cities

PROTECTIVE DEVICES
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities

PULLERS, SLACK
Matthews Corp., W. N., St. Louis

PULLEYS, PAPER
Rockwood Mfg. Co., The, Indianapolis

PUMPS
Allis-Chalmers Mfg. Co., Milwaukee
Goulds Mfg. Co., Seneca Falls, N. Y.

PUMPS, SPIRAL
Cramp & Sons Ship & Engine Bldg. Co., The Wm., Philadelphia

RADIO LABORATORY APPARATUS
General Radio Co., Cambridge, Mass.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RAILWAY SUPPLIES, ELECTRIC
General Electric Co., Schenectady
Ohio Brass Co., Mansfield, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REACTORS
Metropolitan Device Corp., Brooklyn, N. Y.

RECTIFIERS
Fansteel Products Co., Inc., North Chicago
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

REGULATORS, VOLTAGE
Burke Electric Co., Erie, Pa.
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RELAYS
Cory & Son, Inc., Chas., New York
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

RESISTOR UNITS
General Electric Co., Schenectady
Ward Leonard Electric Co., Mt. Vernon, N.Y.

RHEOSTATS
Biddle, James G., Philadelphia
General Electric Co., Schenectady
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

ROPE, WIRE
American Steel & Wire Co., Chicago
Roebling's Sons Co., John A., Trenton, N. J.

SEARCHLIGHTS
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SOCKETS AND RECEPTACLES
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SOLENOIDS
Acme Wire Co., New Haven, Conn.
Belden Mfg. Co., Chicago
Dudlo Mfg. Co., Ft. Wayne, Ind.
General Electric Co., Schenectady
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STARTERS, MOTOR
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
Rowan Controller Co., Baltimore, Md.
Sundh Electric Co., Newark, N. J.
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

STOKERS, MECHANICAL
Sturtevant Company, B. F., Boston
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SUB-STATIONS
General Electric Co., Schenectady
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHBOARDS
Allis-Chalmers Mfg. Co., Milwaukee
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
Metropolitan Device Corp., Brooklyn, N. Y.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

SWITCHES
Automatic Time
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Minerallac Electric Co., Chicago
Sundh Electric Co., Newark, N. J.
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Disconnecting
Burke Electric Co., Erie, Pa.
Condit Electrical Mfg. Corp., S. Boston
Delta-Star Electric Co., Chicago
General Electric Co., Schenectady
K-P-F Electric Co., San Francisco
Matthews Corp., W. N., St. Louis
Thoner & Martens, Boston
Fuse
General Electric Co., Schenectady
Matthews Corp., W. N., St. Louis
Metropolitan Device Corp., Brooklyn, N. Y.
Thoner & Martens, Boston
Knife
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
Matthews Corp., W. N., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Magnetic
Ward Leonard Electric Co., Mt. Vernon, N.Y.
Oil
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Remote Control
Condit Electrical Mfg. Corp., S. Boston
General Electric Co., Schenectady
Rowan Controller Co., Baltimore
Sundh Electric Co., Newark, N. J.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh

TACHOMETERS
Biddle, James G., Philadelphia

TANTALUM
Fansteel Products Co., Inc., North Chicago

TELEGRAPH APPARATUS
Western Electric Co., All Principal Cities

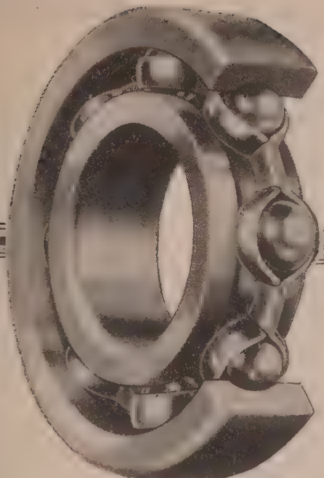
TELEPHONE EQUIPMENT
Cory & Son, Inc., Chas., New York
Western Electric Co., All Principal Cities

TESTING LABORATORIES
Electrical Testing Labs., New York

TOWERS, TRANSMISSION
American Bridge Co., Pittsburgh
Pacific Coast Steel Co., San Francisco
Western Electric Co., All Principal Cities

TRANSFORMERS
Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Duncan Elec. Mfg. Co., Lafayette, Ind.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
General Electric Co., Schenectady
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh
Factory
American Transformer Co., Newark, N. J.
Kuhlman Electric Co., Bay City, Mich.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Wagner Electric Corp., St. Louis
Western Electric Co., All Principal Cities
Furnace
Allis-Chalmers Mfg. Co., Milwaukee
American Transformer Co., Newark, N. J.
Moloney Electric Co., St. Louis
Pittsburgh Transformer Co., Pittsburgh
Metering
American Transformer Co., Newark, N. J.
Ferranti, Ltd., London, Eng.
Ferranti Meter & Transformer Mfg. Co., Ltd., Toronto, Ont.
Pittsburgh Transformer Co., Pittsburgh
Mill Type
Pittsburgh Transformer Co., Pittsburgh
Radio
American Transformer Co., Newark, N. J.
Street Lighting
Kuhlman Electric Co., Bay City, Mich.
Western Electric Co., All Principal Cities

TROLLEY LINE MATERIALS
General Electric Co., Schenectady
Ohio Brass Co., Mansfield, O.
Western Electric Co., All Principal Cities
Westinghouse Elec. & Mfg. Co., E. Pittsburgh



Advantages of ball bearings for electric motors

XII. Higher Efficiency

Motor friction losses cost money,—power money. And anything that reduces such losses means a real dollars and cents saving in the owners pocket.

Here is where ball bearing motors show a decided advantage over motors of any other type.

Assume, for example, that a ball bearing motor is only 2% more efficient than a sleeve bearing motor of the same rated capacity,—and this figure is conservative according to available comparative performance data. Then 30 motors, each delivering 10 H.P. and running 3000 hours a year, would show an annual saving of 30 x 10 x 3000 x .02 = 18,000 H.P. hours. At a cost of 2c a horsepower hour this would amount to a yearly saving in power of $360 for the 30 motors.

Note that this is a saving in power only. It does not include the corresponding savings in lubrication, maintenance, and production losses already considered in previous advertisements of this series.

THIS advertisement is the twelfth of a series appearing monthly in this magazine. Previous advertisements have summarized the following advantages of ball bearings for electric motors:

1. *Short overall length of motor*
2. *No shorts from oily windings*
3. *Clean bearings*
4. *Small, constant air gap*
5. *Reduced maintenance costs*
6. *Thrust load capacity*
7. *Repair bills cut*
8. *Smaller stock of spares*
9. *Belted in any position from any direction*
10. *International interchangeability*
11. *Long life.*

THE FAFNIR BEARING COMPANY

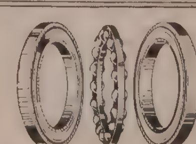
Makers of high grade ball bearings, the most complete line of types and sizes in America

NEW BRITAIN, CONN.

Chicago Newark Cleveland Detroit

FAFNIR

BALL BEARINGS



THE MOST COMPLETE LINE OF TYPES AND SIZES IN AMERICA

Classified Advertiser's Index for Buyers—*Continued*

ALPHABETICAL LIST OF ADVERTISERS

(For classified list of Advertisers see pages 38, 40 and 42.)